

Naval Postgraduate School
Monterey, California 93943-5138

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SUMMARY OF RESEARCH 2000



Department of Aeronautics and Astronautics

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

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PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the four graduate schools (School of International Graduate Studies, Graduate School of Operations and Information Sciences, Graduate School of Engineering and Applied Sciences, and Graduate School of Business and Public Policy) and three Research Institutes (The Modeling, Virtual Environments, and Simulation (MOVES) Institute, Institute for Information Superiority and Innovation (I2SI), and Institute for Defense System Engineering and Analysis (IDSEA). This volume contains research summaries for the projects undertaken by faculty in the Department of Aeronautics and Astronautics during 2000. The summary also contains thesis abstracts for those students advised by Aeronautics and Astronautics faculty during 2000 and 2001.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the Naval Postgraduate School Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, <http://web.nps.navy.mil/~code09/>

Additional published information on the Naval Postgraduate School Research Program can be found in:

- *Compilation of Theses Abstracts:* A quarterly publication containing the abstracts of all unclassified theses by Naval Postgraduate School students.
- *Naval Postgraduate School Research:* A tri-annual (February, June, October) newsletter highlighting Naval Postgraduate School faculty and student research.
- *Summary of Research:* An annual publication containing research summaries for projects undertaken by the faculty of the Naval Postgraduate School.

This publication and those mentioned above can be found on-line at:
<http://web.nps.navy.mil/~code09/publications.html>.

INTRODUCTION

The research program at the Naval Postgraduate School exists to support the graduate education of our students. It does so by providing military relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, to maintain the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focused graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at the Naval Postgraduate School consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- **Reimbursable (Sponsored) Program:** This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with government laboratories and universities, provides off-campus courses either on-site at the recipient command, by VTC, or web-based, and provides short courses for technology updates.
- **Naval Postgraduate School Institutionally Funded Research (NIFR) Program:** The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursably sponsored, and (4) to cost-share the support of a strong post-doctoral program.

In 2000, the level of research effort overall at the Naval Postgraduate School was 137 faculty work years and exceeded \$43 million. The reimbursable program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY2000, over 93% of the research program was externally supported. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2000 is provided in Figure 1.

INTRODUCTION

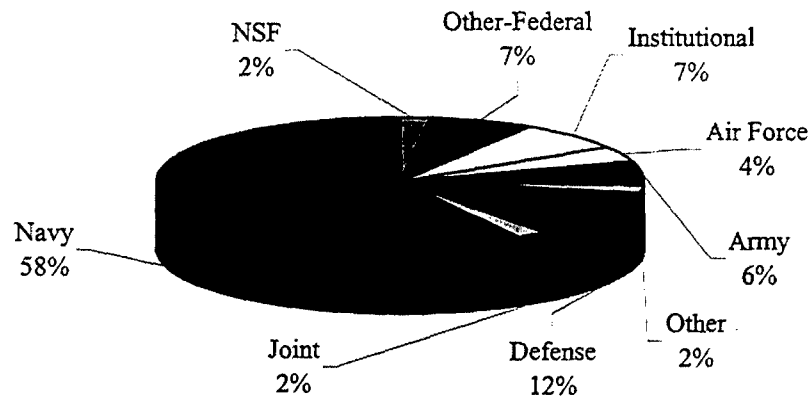


Figure 1. Profile of NPS Research and Sponsored Programs (\$43M)

The Office of Naval Research is the largest Navy external sponsor. The Naval Postgraduate School also supports the Systems Commands, Warfare Centers, Navy Labs and other Navy agencies. A profile of external Navy sponsorship for FY2000 is provided in Figure 2.

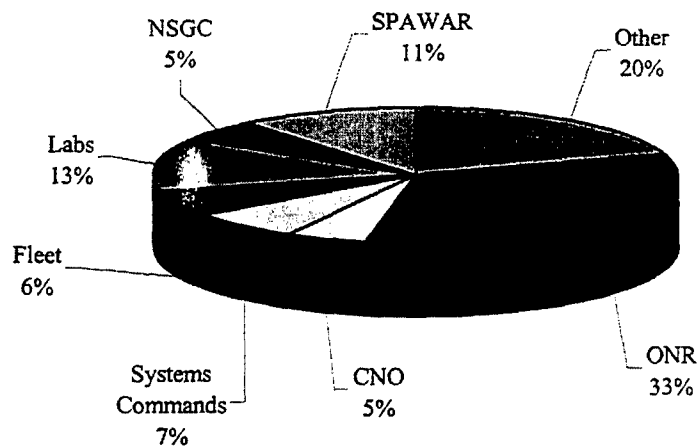


Figure 2. Navy External Sponsors of NPS Research and Sponsored Programs (\$25M)

These are both challenging and exciting times at the Naval Postgraduate School and the research program exists to help ensure that we remain unique in our ability to provide education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

December 2001

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DEPARTMENT SUMMARY

OVERVIEW:

The Department of Aeronautics and Astronautics provides advanced education in Aeronautical and Astronautical Engineering to develop technical subspecialists in the field. Upper division undergraduate and graduate courses are offered in aerodynamics, structures, guidance and control, flight mechanics, propulsion and design, with applications to rotary wing and fixed wing aircraft, missiles and spacecraft.

CURRICULA SERVED:

- Aeronautical Engineering (Curriculum 610)
- Engineering/Avionics (Curriculum 611)
- NPS-TPS Cooperative Program (Curriculum 612)
- Combat Systems Science and Technology (Curriculum 533)
- Space Systems Engineering (Curriculum 591)

DEGREES GRANTED:

- Master of Science in Aeronautical Engineering
- Master of Science in Engineering Science
- Master of Science in Astronautical Engineering
- Aeronautical and Astronautical Engineer
- Doctor of Philosophy
- Doctor of Engineering in Aeronautical and Astronautical Engineering

RESEARCH THRUSTS AND FACULTY EXPERTISE:

- Aerodynamics and Aeroelasticity:
Distinguished Professor Max Platzer, Research Assistant Professor Kevin Jones, Research Professor Muguru Chandrasekhara, and Senior Lecturer Sheshagiri Hebbar
- Aero/Thermodynamics and Laser Technology:
Professor Oscar Biblarz
- Astronautics:
Professor Brij Agrawal and Assistant Professor Michael Spencer
- Avionics:
Associate Professor Russell Duren and Military Instructor CDR Mark Couch, USN
- Design:
Professor Conrad Newberry
- Flight Controls:
Associate Professor Isaac Kaminer
- Flight Mechanics:
Associate Professor Richard Howard
- Helicopter Engineering:
Professor E. Roberts Wood and Research Assistant Professor Ramesh Kolar
- Propulsion:
Distinguished Professor David Netzer and Research Assistant Professor Christopher Brophy
- Spacecraft Dynamics:
Associate Professor I. Michael Ross
- Turbopropulsion and Gasdynamics:
Professor Ray Shreeve and Professor Garth Hobson

DEPARTMENT SUMMARY

RESEARCH FACILITIES:

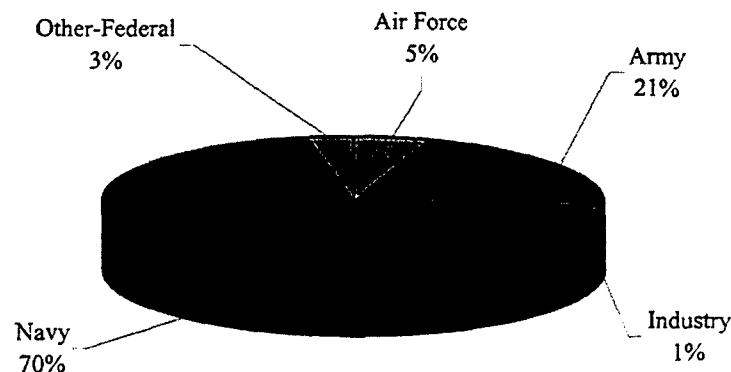
- **Aeronautical Engineering Laboratories:**
 - Subsonic Aerodynamics Laboratory
 - Gas Dynamics Laboratory
 - Combustion Laboratory
 - Turbo-Propulsion Laboratory
 - Computational Instruction Laboratory
 - Flight Mechanics Laboratory
 - Structural Test Laboratory
 - Mechanics of Materials Laboratory
 - Dynamics and Nondestructive Evaluation Laboratory
 - Controls Laboratory
 - Avionics Laboratory
- **Spacecraft Laboratories:**
 - FLTSATCOM Laboratory
 - Spacecraft Test Laboratory
 - Spacecraft Attitude Dynamics Laboratory
 - Spacecraft Design Laboratory

RESEARCH CENTERS:

- Navy-NASA Joint Institute of Aeronautics
- Spacecraft Research and Design Center
- Turbo-Propulsion Laboratory
- Vertical Flight Technology Center

RESEARCH PROGRAM-FY2000:

The Naval Postgraduate School's research program exceeded \$43 million in FY2000. Over 93% of the Naval Postgraduate School Research Program is externally funded. A profile of the external research sponsors for the Department of Aeronautics and Astronautics is provided below along with the size of the FY2000 externally funded program.



Size of Program: \$2012

PROJECT SUMMARIES

SPACECRAFT SYSTEMS

Brij. N. Agrawal, Professor

Department of Aeronautics and Astronautics

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The goal of this project is to develop and operate four spacecraft laboratories: Fltsatcom Laboratory, Spacecraft Test Laboratory, Spacecraft Dynamics and Control Laboratory, and Spacecraft Design Laboratory to support the Space Systems Engineering Curriculum in instruction and experimental research. This is a continuing project.

SUMMARY: During 2000, the major effort has been to make these laboratories operational and upgrade the Spacecraft Design Center with GENSAT software. The progress in making these laboratories operational has been exceptional. Fltsatcom Satellite and TT&C system have become operational. In the Spacecraft Attitude Dynamics Laboratory, the two-link manipulator has become fully operational and the Flexible Spacecraft Simulator is partially operational. In the Smart Structures Laboratory, piezoelectric shape control, piezoelectric active damping, shape memory shape control, and positioning hexapod experiment are operational. In the Spacecraft Design Center, GENSAT is integrated into eight seats and under an MOU between NRO/Aerospace/NPS; Aerospace is providing support to the center in terms of lectures, mentorship, and CDC software. Under AA 4871, students did preliminary design of Relay Mirror Spacecraft.

PUBLICATIONS:

Song, G., Schmidt, S.P., and Agrawal, B., "Active Vibration Suppression of a Flexible Structure Using Smart Material and a Modular Control Patch," *Proceedings of Institution of Mechanical Engineers*, Vol. 214, Part G, 2000, pp. 217-229.

Song, G., Kelly, B., and Agrawal, B., "Active Position Control of a Shape Memory Alloy Wire Actuated Composite Beam," *Journal of Smart Materials and Structures*, Vol. 9, 2000, pp. 711-716.

PRESENTATIONS:

Agrawal, B. and Chen, H. J., "Active Vibration Isolation on Spacecraft Using Smart Struts," IAF-00.I.4.05, 51st International Astronautical Congress, 2-6 October 2000, Rio de Janeiro, Brazil.

Tillier, C. and Agrawal, B., "Yaw Steering for LEO Satellite Using Any Two of Three Reaction Wheels," IAF-00-A.2.01, 51st International Astronautical Congress, 2-6 October 2000, Rio de Janeiro, Brazil.

Bernelli-Zazzera, F., Romano, M., and Agrawal, B., "Experiments on Tracking Control of a Flexible Space Manipulator," IAF-00-A.3.05, International Astronautical Congress, 2-6 October 2000, Rio de Janeiro, Brazil.

THESES DIRECTED:

Ham, W., "Telemetry Systems Analysis and Design," Masters Thesis, Naval Postgraduate School, December 2000.

Bailey, B., "Performance and Space Borne Application Analysis of the Higher Order Cyclostationary Based Classifier," Masters Thesis, Naval Postgraduate School, December 2000.

Whittinghill, C., "A Study of the Feasibility and Applicability of Shape Controlled Space Based Inflatable Membrane Structures," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

PROJECT SUMMARIES

KEYWORDS: Spacecraft Design, Spacecraft Attitude Control, Space Manipulator

ELECTRIC PROPULSION

Oscar Biblarz, Professor

Department of Aeronautics and Astronautics

Sponsor: Unfunded

OBJECTIVE: The goal of this project is to arrive at a specific procedure suitable for preliminary design of space missions where electric propulsion is more attractive than chemical propulsion.

SUMMARY: Electric propulsion has shown to be advantageous over chemical propulsion in a majority of space missions of interest. We extended the Langmuir-Irving payload mass-fraction formulation to a "dual optimum" condition to yield a minimum overall mass for a specified mission/payload which is consistent with minimum propulsion time. This dual optimum allows for the unambiguous selection of one or more electric engines based on their advertised specific impulse, efficiency and a specific power parameter (α in Watts/kg), which represents the power plant. Values of α are tabulated for the present inventory of engines. Examples are worked out for various missions of interest.

PUBLICATION:

Sutton, G. P. and Biblarz, O., *Rocket Propulsion Elements*, 7th Edition, John Wiley and Sons, New York, 2001.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Space Propulsion, Electric Propulsion, Ion Engines, Hall Thrusters, Optimum Specific Impulse, Minimum Thrusting Time

PULSE DETONATION ENGINE (PDE)

Christopher Brophy, Research Assistant Professor

Department of Aeronautics and Astronautics

Sponsors: Office of Naval Research and General Electric Aircraft Engines

SUMMARY: The past year at the laboratory has included an increase in the diversity of sponsors and associated sponsored projects. The Rocket Propulsion and Combustion Laboratory (RPCL) has continued to be active in two primary areas: Pulse Detonation Engine (PDE) and liquid rocket engine technology. Both the Office of Naval Research (ONR) and General Electric Aircraft Engines currently sponsor the PDE research. The ONR related work involves the identification and characterization of two-phase JP10 detonations as well as the investigation of initiator development and detonation wave diffraction issues. The ultimate application of the ONR work is the possible development of a high-speed tactical missile engine system slated for flight Mach numbers between 2 and 5. The results from the past year have agreed well with computational efforts at NRL. I have maintained a strong working relationship between the NRL team so that our collaboration considers the same geometries and conditions. This has been extremely insightful and has aided them in improving the detonation wave propagation predictions. Notable PDE research results over the past year include detonation of a JP10/air aerosol, simultaneous imaging of detonation wave leading shock and heat release region, and initial performance measurements.

A parallel research effort is also underway and sponsored by General Electric Aircraft Engines. They are interested in JP8 as the liquid fuel candidate and would like to address many of the same issues our JP10 research is investigating. The difference in the research programs is that GEAE wants to apply this research to a conventional military jet engine where the afterburner is replaced by a PDE augmentor. The NPS results will be used to aid GE in developing the prototype system proposed by GEAE on the NASA "REVCON" project which they have won last year.

PROJECT SUMMARIES

The liquid fuel rocket engine work has progressed and we are now evaluating various film-cooling geometries. These geometries are designed to imitate real-world systems and allow us to characterize the plumes using multi-wavelength transmission (MWT), IR imagers, and FTIR spectrometers. The MWT apparatus was improved by utilizing diode lasers and shifting the transmission lines to slightly higher wavelengths for better S/N ratios and to minimize molecular absorption concerns. The signature characterization work is sponsored by the Air Force Research Lab at Edwards Air Force base.

Since the liquid rocket engine is design to run in a film-cooled mode, a company called Sierra Engineering is co-sponsoring the lab to investigate the performance of transpiration cooled motor segments. These segments transpire fuel through 30-micron holes in the wall to keep the walls below material limits. This work is of interest to the Air Force as well as NASA, both of which also support this work. This work could allow future liquid rocket engines to be designed with a more optimum wall-cooling concept than is currently used.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Pulse Detonation Engine, Liquid Rocket Engine

THE EFFECTS OF ROCKET MOTOR OPERATING CONDITIONS ON EXHAUST PLUME SOOT CONCENTRATIONS AND IR SIGNATURE

Christopher Brophy, Research Assistant Professor

David Netzer, Distinguished Professor

Department of Aeronautics and Astronautics

Sponsor: Air Force Research Lab

OBJECTIVE: To experimentally determine the effects of motor operating conditions, fuel composition and fuel additives on the exhaust plume soot characteristics and plume signature of gaseous oxygen/liquid-fuel rocket motors.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Rocket Motors, Plumes, Soot

FLUID MECHANICS OF COMPRESSIBLE DYNAMIC STALL CONTROL USING DYNAMICALLY DEFORMING AIRFOILS

M.S. Chandrasekhara, Research Professor

Department of Aeronautics and Astronautics

Sponsor: U.S. Army Research Office

OBJECTIVE: To develop flow control schemes through management of the unsteady vorticity field by dynamically deforming an airfoil for prevention of flow separation.

SUMMARY: This year the research effort was focused on testing the 6-inch chord NACA 0012 airfoil instrumented with 148 surface hot-film gages to identify the surface shear stress behavior in this flow. The surface flow was documented for a range of flow conditions representative of that encountered by a helicopter retreating blade. For the first time, the upstream movement of the transition point in unsteady compressible flow was quantified. Also, the onset of the laminar separation bubble and the effects of shock formation on the surface flow were captured. Considerable new information has been generated, which it is hoped will provide new insight into the dynamic stall mechanism onset. Presently, the use of digital filtering is being explored to extract only the low frequency content of the surface shear stress signature to identify possible new mechanisms. Also, tests with a three-sensor approach, with varying overheat ratios, for detecting local flow reversals are being planned. In these, voltages from a set of three closely spaced

PROJECT SUMMARIES

sensors will be obtained and the output from the outer two compared with that from the central sensor to record instantaneous flow details.

PUBLICATIONS:

Chandrasekhara, M.S., Wilder, M.C., and Carr, L.W., "Compressible Dynamic Stall Control: A Comparison of Different Approaches," AIAA-99-3122, to appear in *AIAA Journal of Aircraft*.

Sahin, M., Sankar, L.N., Chandrasekhara, M.S., and Tung, C., "Dynamic Stall Alleviation Using a Deformable Leading Edge Concept – A Numerical Study," AIAA Paper 00-0520, Reno, NV, January 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Flow Control, Helicopter Blade Stall, Smart Materials, Deforming Airfoils

USE OF OSCILLATORY BLOWING TO CONTROL COMPRESSIBLE DYNAMIC STALL BEHAVIOR OF AN OSCILLATING NACA 0015 AIRFOIL

**M.S. Chandrasekhara, Research Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Aero Flight Dynamics Directorate,
National Aeronautics and Space Administration**

OBJECTIVE: To investigate compressible dynamic stall control using the oscillatory blowing technique on a trailing edge stalling oscillating NACA 0015 airfoil.

SUMMARY: This effort aims to control compressible dynamic stall using oscillatory blowing. A 0.02-inch blowing slot at 20 deg to the upper surface of a 6-inch chord NACA 0015 airfoil, was connected to a Boeing Company supplied high frequency, high amplitude actuator powered by a two channel audio receiver, via a symmetric plenum housed inside the airfoil. A dynamic pressure transducer installed in the plenum chamber recorded the pressure fluctuations as the airfoil oscillated and blowing was activated. Point diffraction interferograms were obtained at different flow conditions along with unsteady pressure in the plenum chamber. Preliminary trials at controlling stall were found to be successful. However, the strong airfoil peak suction pressure caused the actuator diaphragm to be pushed to one end of its stroke, eliminating most of its pumping ability. This problem is being addressed by building a vacuum enclosure to balance the pressure on both sides of the diaphragm. A more powerful blowing system is also being supplied by The Boeing Company to enhance chances of success.

PUBLICATION:

Ekaterinaris, J.A. and Chandrasekhara, M.S., "Numerical Investigation of Passive and Active Control of Unsteady Compressible Flow," AIAA Paper 00-4417, Denver, CO, August 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Flow Control, Helicopter Blade Stall, Oscillatory Blowing

PROJECT SUMMARIES

CONTROL COMPRESSIBLE DYNAMIC STALL USING A VARIABLE DROOP LEADING EDGE VR-12 AIRFOIL

M.S. Chandrasekhara, Research Professor

Department of Aeronautics and Astronautics

Sponsor: U.S. Army Aero Flight Dynamics Directorate,

National Aeronautics and Space Administration

OBJECTIVE: To investigate compressible dynamic stall control using a Variable Droop Leading Edge (VDLE) Concept.

SUMMARY: In an attempt to develop new ways of controlling dynamic stall that can exploit the progress in smart materials, a new concept of drooping the airfoil leading edge steadily as it pitches up is being tested in this project. The idea is to reduce maintain low leading edge incidence while the airfoil is at high angles of attack to avoid leading edge stall onset. The technique holds special promise for compressible dynamic stall control since it is a leading edge type of stall. During the first few months since initiation, a 6-inch chord VR-12 (Boeing Vertol) airfoil has been designed, and fabricated with 20 unsteady pressure transducers installed on it. The design incorporates features to bring out all the power and signal leads through the $\frac{1}{4}$ -chord point, the only stationary point in the system. The leading 25% of the airfoil can droop to as large as -25° relative to the main element dynamically and it can be preset to any desired value as well. The design is now ready for testing in the Compressible Dynamic Stall Facility. The pressure transducers will be calibrated in a specially designed chamber and will account for temperature changes in the system. Integrated force and moment loops will be calculated for rotor retreating blade conditions to demonstrate the success of the approach.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Variable Geometry Airfoils, Dynamic Stall, Rotor Blade Flow Control

VORTEX RING STATE WARNING SYSTEM RESEARCH AND VALIDATION

CDR Mark A. Couch, USN, Military Instructor

Russell W. Duren, Associate Professor

Department of Aeronautics and Astronautics

Sponsor: Office of Naval Research

OBJECTIVE: The objective of this proposal is to continue research into the vortex ring state and to promote and support flight testing, validation and transition efforts to field the vortex ring state warning system developed under previous NSAP funding (NSAP Task Number: CNAL-1.2.99-TSP).

SUMMARY: Under NSAP Task Number: CNAL-1.2.99-TSP, LCDR Dave Varnes, Dr. Russ Duren and Dr. E. R. Wood had previously completed research into the vortex ring state (VRS) leading to the development and demonstration of a pilot warning system targeted specifically for the CH-60 helicopter. During 2000 the previous research was extended in two areas. First, the warning systems was refined and expanded. A Windows program was developed to provide a demonstration version of the warning system. The user interface (GUI) was refined and the program was expanded to allow the user to select multiple helicopter and tiltrotor aircraft. The second area of research included a further analysis of flight data available concerning VRS. The analysis was based on flight test data for a NASA H-34 helicopter. Additional information was obtained through discussions with engineers from Boeing and Westland Helicopter and at several conferences and workshops. Recovery techniques were discussed with instructors at Great Britain's Empire Test Pilot School. This is the only flight school that teaches pilots how to recognize and recover from VRS with actual flight experiences. After the unfortunate crash of a MV-22 on April 8, 2000, the research took on the additional tasks of supporting the accident investigation and additional flight-testing of the MV-22. Research into VRS is continuing on a slower pace in 2001 as an unfunded project.

PROJECT SUMMARIES

PUBLICATIONS:

Varnes, D., Duren, R., and Wood, E. R., "Detecting the Vortex Ring State," *Rotor & Wing*, Vol. 34, No. 1, pp. 60-65, January 2000.

Varnes, D., Duren, R., and Wood, E. R., "An Onboard Warning System to Prevent Hazardous 'Vortex Ring State' Encounters," *Proceedings of the 26th European Rotorcraft Forum*, pp. 88-122, The Hague, The Netherlands, 26-29 September 2000.

PRESENTATIONS:

Duren, R.W., Wood, E.R., and Couch, M.A., "NPS Vortex Ring State Definition and Safety Data Review," Rotorcraft Aeromechanics Workshop, Naval Air Systems Command, Patuxent River, MD, 18-19 July 2000.

Wood, E.R., Couch, M.A., and Duren, R.W., "NPS Research on Vortex Ring State," Rotorcraft Aeromechanics Workshop, Naval Air Systems Command, Patuxent River, MD, 18-19 July 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Other (Avionics, Safety)

KEYWORDS: Avionics, Pilot Aid, Safety, Vortex Ring State

AIR-GROUND RAPID RETARGETING SYSTEM

Russell W. Duren, Associate Professor

Isaac Kaminer, Associate Professor

Department of Aeronautics and Astronautics

Sponsor: Naval Air Systems Command

OBJECTIVE: Time Critical Strike has been identified as a high priority area of research by multiple studies. The goal of time critical strike is to rapidly target and attack enemy forces and systems that can move and hide frequently, also known as Time Sensitive Targets. This research examines the problems associated with attacking a moving target using low cost GPS-aided standoff weapons, without an integrated weapon seeker.

SUMMARY: Research during 2000 concentrated on investigating design requirements and technical problems related to the development of a closed system, which will generate and transmit targeting information using the existing/planned, C4I system to provide off-board retargeting information to a generic GPS-guided standoff weapon. A conceptual system was developed that used generic sensor platforms and a ground-based targeting processor to provide targeting data to a generic standoff weapon via a Link-16 data link. A simulation model was developed in order to investigate the response of the proposed system to various combinations of identified error sources. The preliminary design of a simulation model was completed. Initial coding of the simulation model was performed using Statemate MAGNUM from I-Logix, Inc. Final coding is continuing in 2001 using MATLAB® Simulink®. The simulation model is being developed in a modular fashion to allow future expansion. Initially generic modules are being used for the target behavior, the sensors, the targeting processor, the data link, the weapon flight characteristics, and the weapon effects on the target. Due to the modular nature of the simulation model each of these modules will be capable of being replaced by more sophisticated or less generic modules in the future.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Command, Control and Communications, Conventional Weapons, Sensors, Modeling and Simulation, Other (Time Critical Strike)

KEYWORDS: Time Critical Strike, Time Sensitive Targets, RTIC; Real-time Information in the Cockpit, Targeting GPS, Weapon, Modeling, CEP, Command, Control and Communications, Conventional Weapons, Stand-off Weapons, Sensors, Modeling and Simulation

PROJECT SUMMARIES

EA-6B FOLLOW-ON PLATFORM CAPABILITIES STUDY

CAPT Jim Powell, USN, Military Instructor
Information Warfare Academic Group
Russell W. Duren, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Chief Naval Operations (N88)

OBJECTIVE: This study is tasked to support N88 requirements definition in the Airborne Electronic Attack (AEA) Analysis of Alternatives (AoA) process by outlining and prioritizing technical alternatives for future TACAIR Electronic Attack, and by developing a roadmap to use in the conduct of the EA-6B Follow-on Platform AOA.

SUMMARY: Research was completed providing surveys of available information and systems that could be used to support the AEA AoA. A report was completed that surveyed previous AEA studies. The report summarized classified and unclassified studies from the time period of 1992 through 1999. It concluded with recommendations for future research. A set of surveys was performed as part of a master's thesis. These surveys examined a wide range of existing and proposed systems for potential use in an AEA system of systems. Systems that were surveyed included UAV and UCAV platforms; avionics payloads for reconnaissance, SIGINT, and various forms of electronic attack; and smart weapon platforms for SEAD and DEAD missions.

OTHER:

Duren, R. W., "Report on Previous Studies Related to the EA-6B Follow-on Platform," paper provided to the AEA AoA Technical IPT, June 2000.

THESIS DIRECTED:

Nance, L., "EA-6B Follow-On Study: UAVS and UCAVS," Master's Thesis, Naval Postgraduate School, March 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: EA-6B, Electronic Warfare, Prowler, SEAD, Shielding, Slot Antenna, Smart Weapons, Unmanned Combat Air Vehicles, UCAV, Unmanned Air Vehicles, UAV, Electronic Attack

F/A-18 C/D AVIONICS ARCHITECTURE STUDY

Russell W. Duren, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center- Weapons Division

OBJECTIVE: Work with F/A-18 Advanced Weapons Laboratory personnel to develop a system-wide assessment of the F/A-18 C/D avionics system. Identify growth requirements and factors limiting growth over the next 20 to 30 years. Develop a list of potential solutions identifying costs and benefits associated with each solution. Identify best solution(s) and develop a funding schedule for implementation.

SUMMARY: Research on this project started in the last month of 2000 and concentrated gathering information on the existing avionics architecture and its performance. This is the first phase of what is projected to be a multi-year project. Initial reporting dates for the first phase of the project are scheduled in March, April and August of 2001.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Conventional Weapons, Electronics, Human Systems Interface, Sensors, Modeling and Simulation, Other (Avionics)

PROJECT SUMMARIES

KEYWORDS: Avionics, Avionics Data Bus, Avionics Architecture, Computer Architecture, COTS, Displays, Fibre Channel, Legacy Upgrades, Microprocessor Emulators, MIL-STD-1553, Mission Systems, Software Translation, System-level Simulation

INCORPORATION OF ENHANCED GROUND PROXIMITY WARNING SYSTEM (EGPWS) IN THE NASA AMES RESEARCH CENTER

CAE BOEING 747-400 FLIGHT SIMULATOR

Russell W. Duren, Associate Professor

Department of Aeronautics and Astronautics

Sponsor: National Aeronautics and Space Administration-Ames Research Center

OBJECTIVE: Perform a trade study to determine the best method of incorporating EGPWS functionality into the Crew Vehicle Systems Research Facility (CVSRF) 747-400 simulator, obtain approval and funding for the project, and begin the design.

SUMMARY: A trade study was performed to determine the best method of incorporating EGPWS functionality into the CVSRF 747-400 simulator. Options considered in the trade study included rehosting vendor supplied software, developing simulation code from scratch, and installing a commercial EGPWS unit. Based on the results of the study, a decision was made to install a commercial EGPWS box in the simulator. Funding was obtained and a work package was developed to allow the design task to proceed. The design task included defining the electrical and mechanical interface to the simulator. This task included interfacing with hardware and software simulations of the pilot displays that were unique to the flight simulator environment. The completed hardware design specified multiple control panels, all of the cables and mechanical hardware to install the system, and a system of four personal computers with special graphics cards to perform the display task. The software design was specified at a top level, but not completed as part of this research.

THESIS DIRECTED:

Degennaro, R.A., "Incorporation of an Enhanced Ground Proximity Warning System (EGPWS) in the NASA Ames Research Center CAE Boeing 747-400 Flight Simulator," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Electronics, Human Systems Interface, Modeling and Simulation

KEYWORDS: EGPWS, Flight Simulation, Full Flight Simulator, GPWS, Ground Proximity Warning System

ANALYSIS OF TRACKING CHARACTERISTICS AND ID CONTRIBUTIONS OF DIVERSE SYSTEMS AND DATA SOURCES FOR MULTIPLE SOURCE INTEGRATION (MSI)

LCDR Dean A. Wilson, USN, Student

Russell W. Duren, Associate Professor

Department of Aeronautics and Astronautics

Sponsor: Naval Air Warfare Center-Aircraft Division

OBJECTIVE: This research supports Multiple Source Integration/Data Fusion (MSI/DF) initiatives being developed by PMA-231, Northrop-Grumman Corporation, and the Office of Naval Research for the E-2C Hawkeye aircraft. The MSI/DF concept seeks to provide a single fused track for each contact of interest in the battlespace. A fused track will be representative of all available sources of data contributing to that track. The Combat Identification process will tie together all identifying attributes of these tracks to enable a CID decision based on the track identification parameters and other parameters.

PROJECT SUMMARIES

SUMMARY: Research completed in 2000 included performing an analysis of previous work performed in the subject area. In addition, work was begun to develop a computer simulation using the MATLAB® programming environment. The goal of the simulation is to provide a test bed for multiple tracking, sensor fusion and combat identification algorithms.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Command, Control and Communications, Computing and Software, Human Systems Interface, Sensors, Modeling and Simulation

KEYWORDS: Combat Identification, Data Fusion, Kalman Filtering, Multiple Source Integration, Tracking

EXPLORATION OF FIBRE CHANNEL AS AN AVIONICS INTERCONNECT FOR THE 21ST CENTURY MILITARY AIRCRAFT

LCDR Shawn P. Hendricks, USN, Student

Russell W. Duren, Associate Professor

Department of Aeronautics and Astronautics

Sponsor: Naval Air Warfare Center-Aircraft Division

OBJECTIVE: To gain insight into the applicability of Fibre Channel in a military aircraft infrastructure. Fibre Channel systems are being adopted as the successor to MIL-STD-1553 on many military aviation platforms. This research will allow service Program Managers to make better decisions about future procurement of avionics systems that use Fibre Channel as their primary interconnect topology.

SUMMARY: This research evaluated Fibre Channel as avionics interconnection standard. It began by defining the requirements and measures of performance for an interconnection system suitable for new avionics architectures. The requirements address technical performance, affordability, reliability, sustainability, and maintainability considerations. The Fibre Channel standard was then briefly compared to the requirements for the avionics interconnection system. In order to perform a technical performance evaluation of a switched fabric avionics interconnection system, a computer simulation model was developed. The OPNET Modeler® tool from OPNET, Inc. was used to model the components of an advanced avionics system. This tool allows multiple system configurations to be defined and examined quickly, showing both the advantages of one configuration over another as well as potential problem areas. The simulation model, simulation results and conclusions were documented in a conference presentation and a thesis.

PUBLICATION:

S. Hendricks, S. and Duren, R., "Using OPNET to Evaluate Fibre Channel as an Avionics Interconnection System," *Proceedings of the 19th Digital Avionics Systems Conference*, pp. 4.C.1-1-8, Philadelphia, PA, 7-13 October 2000.

THESIS DIRECTED:

Hendricks, S. P., "Exploration of Fibre Channel as an Avionics Interconnect for the 21st Century Military Aircraft," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Electronics, Modeling and Simulation

KEYWORDS: Avionics, Communications, Data Bus, Digital Interconnect, Fibre Channel, MIL-STD-1553, Modeling, Serial Interface, Simulation

PROJECT SUMMARIES

TURBINE TIP-LEAKAGE FLOWS

G. V. Hobson, Associate Professor

Department of Aeronautics and Astronautics

Sponsors: Naval Air Warfare Center-Aircraft Division and Naval Postgraduate School

OBJECTIVE: This project entails non-intrusive, laser-Doppler-velocimetry (LDV) measurements, in the endwall region of a turbine. A paper was presented at the Aerospace Sciences Conference in Reno, NV in January 2001. The specific turbine test article is the turbine of the High Pressure Fuel TurboPump (HPFTP) of the Space Shuttle Main Engine (SSME) and the particular hardware was designed and manufactured by Pratt & Whitney for NASA.

SUMMARY: LCDR Anderson continued the project by first improving on the numerical predictions. He used a more advanced two-equation ($k-\epsilon$) turbulence model. Next he was able to obtain a complete set of LDV measurements over the tips of the turbine rotor blades, at three axial stations and at three radial depths. These measurements were taken through an aerodynamic window, which vented air from within the turbine to the outside. Failure of the quill shaft, which connected the turbine to the power absorbing dynamometer, halted further tests. The quill shaft and dynamometer have been repaired and a follow on student is needed to continue the measurements through a pressurized aerodynamic window.

PUBLICATION/PRESENTATION:

Hobson, G.V., Anderson, S.C., McKee, J. and Southward, J., "Experimental and Numerical Investigation of the Tip Leakage Flow in the Single Stage Turbine of the Space Shuttle Turbopump," AIAA 2001-0831, 39th Aerospace Sciences Conference, Reno, NV, January 2001.

THESIS DIRECTED:

Anderson, C.S., "Analysis of the Tip Leakage Flow Field in an Axial Turbine," Engineers Thesis, Naval Postgraduate School, June 1999.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Turbine, Laser, Velocimetry, Tip-leakage Flows

CONTINUED DEVELOPMENT OF THE AFFORDABLE GUIDED AIRDROP SYSTEM

Richard M. Howard, Associate Professor

Department of Aeronautics and Astronautics

Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: To continue efforts in the development of a low-cost guidance, navigation, and control system for airdrop leading to the demonstration of autonomous guidance of a flat-circular parachute; and to support this effort with simulation, hardware development, model development, instrumentation development, and assistance with data analysis, test planning, and system demonstration.

SUMMARY: This part of the project had two components: 1) the development of an aerodynamic model of a controlled flat-circular parachute, and 2) the development of an instrumentation package for personnel parachute application. The previous development of round parachute aerodynamic models was reviewed, and a five-degree-of-freedom model was proposed. An instrumentation package consisting of a datalogger, three low-cost rate sensors, three linear accelerometers, a pressure sensor and a GPS card was designed based on similar work at NASA Dryden Flight Research Center. Further parachute model development and instrumentation package development and testing will continue in 2001.

PROJECT SUMMARIES

PUBLICATION:

Dellicker, S., Williams, T., Hewgley, C., Yakimenko, O., Howard, R., Kaminer, I., Benney, R., and Patel, S., "Performance, Control, and Simulation of the Affordable Guided Airdrop System," *Proceedings of the 2000 AIAA Conference on Guidance, Navigation and Control*, Denver, CO, August 2000.

DoD KEY TECHNOLOGY AREAS: Electronics, Sensors, Modeling and Simulation

KEYWORDS: Parachute, Modeling, Datalogger, Instrumentation

SSAT TECHNOLOGY ASSESSMENT AND RISK REDUCTION STUDY-WET WING DESIGN STUDY FOR SUBSCALE AERIAL TARGETS

Richard M. Howard, Associate Professor
Ramesh Kolar, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: Aerial Target Systems

OBJECTIVE: To conduct a wet-wing design study for Subscale Subsonic Aerial Targets (SSATs). The tools developed may be used for the evaluation of the structural technologies for the Joint Subscale Aerial Target (JSAT).

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Aerial Target, Unmanned Aerial Vehicle, Wet-Wing

PASSIVE SENSOR-BASED CONTROL OF NONLINEAR AUTONOMOUS SYSTEMS

I. I. Kaminer, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this proposal is to investigate sensor fusion architectures and mathematical algorithms required to support autonomous vertical take off and landing (VTOL) of uninhabited combat air vehicles on ships using passive sensors. Preliminary results were obtained on the synthesis of time-varying and nonlinear filters that integrate vision, GPS and inertial sensors to provide an accurate estimate of ship's position with respect to the aircraft as well as of the ship's inertial velocity.

PUBLICATIONS:

Yakimenko, O.A., Kaminer, I.I., Lentz, W.J., and Ghyzel, P.A., "Unmanned Aircraft Navigation for Shipboard Landing Using Infrared Vision," *Proceedings 2000 American Control Conference*, June 2000, Chicago, IL.

Kaminer, I.I., Pascoal, A.M., Kang, W., and Yakimenko, O.A., "Integrated Vision/Inertial Navigation Systems Design Using Nonlinear Filtering," *Proceedings 2000 Conference on Decision and Control*, Sydney, Australia.

Pascoal, M., Kaminer, I.I., and Oliveira, P., "Design of the Complementary, Time-Varying Filters Using Linear Matrix Inequalities," *IEEE Transactions on Aerospace and Electronics*, Vol. 36, No. 4, pp. 1099-1114.

Kaminer, I., Pascoal, A.M., Kang, W., and Yakimenko, O., "Integrated Vision/Inertial Navigation Systems Design Using Nonlinear Filtering," to appear in *IEEE Transactions on Aerospace and Electronics*.

PROJECT SUMMARIES

OTHER:

Kaminer, I., *Passive Sensor Based Control of Nonlinear Systems*, ONR Contractor Report, Contract No. N0001497AF00002.

THESIS DIRECTED:

Ghyzel, P.A., "Vision-Based Navigation for Autonomous Landing of Unmanned Aerial Vehicles," Engineers Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Unmanned Combat Air Vehicles, Sensor Fusion, Robust Sensor-Based Control, Multi-Spectral, Neural Sensor Processing

CONTINUED DEVELOPMENT OF THE AFFORDABLE GUIDED AIRDROP SYSTEM (AGAS)

I. I. Kaminer, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: Continue efforts in the development of a low-cost guidance, navigation and control system for airdrop leading to the demonstration of autonomous guidance of a flat circular parachute, to support this effort with simulation, hardware development, model development, instrumentation development and assistance with data analysis, test planning and system demonstration.

PUBLICATION:

Dellicker, S., Williams, T., Hewgley, C., Yakimenko, O., Howard, R., Kaminer, I., Benney, R., and Patel, S., "Performance, Control, and Simulation of the Affordable Guided Airdrop System," *Proceedings 2000 AIAA Conference on Guidance, Navigation and Control*, August 2000, Denver, CO.

THESIS DIRECTED:

Williams, T., Optimal Parachute Guidance, Navigation, and Control for the Affordable Guided Airdrop Systems (AGAS), Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Airdrop, Parachutes, Autonomous Guidance, Modeling

INTEGRATION AND FLIGHT TEST OF UCLA'S NAVIGATION COMPUTER ON NPS UAV FROG

I. I. Kaminer, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: National Aeronautics and Space Administration-Goddard

OBJECTIVE: The objective of this proposal is to integrate and flight test the navigation computer developed by UCLA and NASA Goddard on NPS's UAV Frog. Specifically formation flights that include the Frog and UCLA's UAV Mule will be conducted at Camp Roberts flight test range starting in May of 2000 and completing in September of 2001.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

PROJECT SUMMARIES

KEYWORDS: Unmanned Air Vehicles, Flight Test

IMPROVED TARGET ACCURACY AND SENSOR AIMING FOR RAH-66 WEAPONS SYSTEM

Ramesh Kolar, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: Using the MSC/NASTRAN structural dynamic model of the RAH-66 helicopter, determine biases between sensors lose and weapon pointing to the target for specified conditions as a function of the flight envelope. Weapons of interest are three-barrel, nose mounted 20mm turreted Gatling gun. Sensors include FCR, TV, and FLIR. Actual measured gun loads will be used for the analysis.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Helicopter, Rotorcraft, Dynamics, Structures, NASTRAN

LONG ENDURANCE NAVAL SUPPORT UNINHABITED COMBAT AIR VEHICLES (UCAVs)

Conrad Newberry, Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research

OBJECTIVE: The primary objective of this proposal is to define the system integration issues for a notional UCAV capable of performing long endurance naval support for the Littoral Battlespace.

DoD KEY TECHNOLOGY AREAS: Human-System Interfaces

KEYWORDS: Uninhabited Combat Air Vehicle, Long Endurance, Naval Support

COMPUTATIONAL AND EXPERIMENTAL INVESTIGATIONS OF VARIOUS AERODYNAMIC AND AEROELASTIC PROBLEMS

M.F. Platzer, Distinguished Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research

OBJECTIVE: Perform computational and experimental investigations of various steady and unsteady aerodynamic and aeroelastic problems.

SUMMARY: The dynamic stall characteristics and of the NLR 7301 airfoil and of the Buffum cascade was analyzed using a Navier-Stokes code. Also, the effect of wind tunnel interference on the transonic flutter characteristics of the NLR 7301 airfoil was analyzed using the same Navier-Stokes code. Furthermore, the effect of Reynolds number on the vortical flow over double-delta wings was investigated in water tunnel tests.

THESIS DIRECTED:

Gossett, D.H., "Investigation of Cross-Flow Fan Propulsion for Lightweight VTOL Aircraft," Masters Thesis, Naval Postgraduate School, December 2000.

PROJECT SUMMARIES

PUBLICATIONS:

Weber, S. and Platzer, M.F., "Computational Simulation of Dynamic Stall on the NLR 7301 Airfoil," *Journal of Fluids and Structures*, Vol. 14, pp. 779-798, 2000.

Weber, S. and Platzer, M.F., "A Navier-Stokes Analysis of the Stall Flutter Characteristics of the Buffum Cascade," *Journal of Turbomachinery*, Vol. 122, pp. 769-776, October 2000.

Hebbar, S.K., Platzer, M.F., and Fritzels, A.E., "Reynolds Number Effects on the Vortical-Flow Structure Generated by a Double-Delta Wing," *Experiments in Fluids*, Vol. 28, pp. 206-216, 2000.

PRESENTATIONS:

Castro, B.M., Ekaterinaris, J.A., and Platzer, M.F., "Transonic Flutter Computations for the NLR 7301 Airfoil Inside a Wind Tunnel," AIAA Paper 2000-0984, 38th Aerospace Sciences Meeting, Reno, NV, 10-13 January 2000.

Weber, S. and Platzer, M. F., "A Navier-Stokes Analysis of the Stall Flutter Characteristics of the Buffum Cascade," ASME Paper No. 2000-GT-385, International Gas Turbine Congress, Munich, Germany, 8-11 May 2000.

DoD KEY TECHNOLOGY AREAS: Other (Aerodynamics)

KEYWORDS: Separated Flow, Transonic Flow, Vortical Flow, Flutter

ASRAAM MISSILE LAUNCH LOAD ANALYSIS

M. F. Platzer, Distinguished Professor

Department of Aeronautics and Astronautics

Sponsor: Naval Air Warfare Center-Aircraft Division

OBJECTIVE: The objective of the proposed investigation is to provide support services for the ASRAAM Missile High G (tip off) Launch Load Analysis.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Unsteady Aerodynamics, Flapping Wing Propulsion, Unmanned Air Vehicles

DEVELOPMENT OF SMALL UNMANNED AIR VEHICLE

M. F. Platzer, Distinguished Professor

K.D. Jones, Research Assistant Professor

Department of Aeronautics and Astronautics

Sponsor: Naval Research Laboratory

OBJECTIVE: The objective of the proposed effort is the exploration and demonstration of flapping wing propulsion for small-unmanned air vehicles

SUMMARY: Several micro-air-vehicle models of varying scales and complexity were built and tested which use two airfoils that are flapping in counterphase with variable frequency and amplitude. The thrust was measured with a laser device and compared with the numerical results obtained with a previously developed inviscid unsteady panel code.

PROJECT SUMMARIES

THESES DIRECTED:

Lund, T.C., "A Computational and Experimental Investigation of Flapping-Wing Propulsion," Masters Thesis, Naval Postgraduate School, March 2000.

Duggan, S., "An Experimental Investigation of Flapping Wing Propulsion for Micro Air Vehicles," Masters Thesis, Naval Postgraduate School, June 2000.

PUBLICATION:

Tuncer, I.H. and Platzer, M.F., "Computational Study of Flapping Airfoil Aerodynamics," *Journal of Aircraft*, Vol. 37, No. 3, pp. 514-520, May-June 2000.

PRESENTATIONS:

Jones, K.D. and Platzer, M.F., "Flapping Wing Propulsion for a Micro Air Vehicle," AIAA Paper No. 2000-0897, 38th Aerospace Sciences Meeting, Reno, NV, 10-13 January 2000.

Jones, K.D., Lund, T.C., and Platzer, M.F., "Experimental and Computational Investigation of Flapping-Wing Propulsion for Micro-Air Vehicles," presented at the Conference on Fixed, Flapping and Rotary Wing Vehicles at Very Low Reynolds Numbers, University of Notre Dame, Notre Dame, IN, June 5-7, 2000.

Jones, K.D., Lai, J.C.S., Tuncer, I.H., and Platzer, M.F., "Computational and Experimental Investigation of Flapping-Foil Propulsion," presented at First International Symposium on Aqua Bio-Mechanisms, Tokai University Pacific Center, Honolulu, HI, 27-30 August 2000.

Platzer, M.F. and Jones, K.D., "The Unsteady Aerodynamics of Flapping -Foil Propellers," presented at Ninth International Symposium on Unsteady Aerodynamics and Aeroelasticity of Turbomachines, Lyon, France, 5-8 September 2000.

DoD KEY TECHNOLOGY AREAS: Other (Aerodynamics/Hydrodynamics)

KEYWORDS: Unsteady Aerodynamics, Unmanned Air Vehicles, Flapping Wing Propulsion

AEROELASTIC STUDIES OF HYPERSONIC MISSILE FINS

M. F. Platzer, Distinguished Professor

Ramesh Kolar, Research Assistant Professor

Department of Aeronautics and Astronautics

Sponsor: Naval Air Warfare Center-Weapons Division

OBJECTIVE: The objective of this work is to perform an exploratory flutter analysis of the fins on the proposed Navy Hypersonic Weapons Technology Missile.

SUMMARY: A report was delivered which summarizes the vibration and flutter analysis of a representative fin using the MSC-NASTRAN code.

DoD KEY TECHNOLOGY AREAS: Other (Design Automation)

KEYWORDS: Aeroelasticity, Missile Aerodynamics, Hypersonic Flow

PROJECT SUMMARIES

COMPUTATIONAL STUDY OF ABRUPT WING STALL

M.F. Platzer, Distinguished Professor

K.D. Jones, Research Assistant Professor

Department of Aeronautics and Astronautics

Sponsor: Office of Naval Research and Naval Air Warfare Center-Patuxent River

OBJECTIVE: Computational prediction of abrupt transonic wing stall on modern fighter/attack aircraft configurations using advanced Navier-Stokes codes.

SUMMARY: Three-dimensional Navier-Stokes computations of the F-18 E/F configurations are performed to establish criteria for the onset of abrupt wing stall.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Aerodynamics, Transonic Flows, Separated Flows, Vortical Flows, Computational Fluid Dynamics

SABBATICAL RESEARCH AT DRAPER LABS

I.M. Ross, Associate Professor

Department of Aeronautics and Astronautics

Sponsor: Naval Surface Warfare Center-Crane Division

OBJECTIVE: This proposal is for researching the design of optimal gimballed tumbling for INS error reduction during the boost and bus phases of the Trident Missile. The task will be performed as part of the PI's sabbatical at The Charles Stark Draper Laboratory in Cambridge, MA.

SUMMARY: This is a classified project and not much can be said about the work performed beyond what is stated in the objective.

PUBLICATIONS:

Fahroo, F. and Ross, I.M., "A Spectral Patching Method for Direct Trajectory Optimization," *The Journal of the Astronautical Sciences*, Vol. 48, No. 2/3, April-September 2000.

Fahroo, F. and Ross, I.M., "A Second Look at Approximations to Differential Inclusions," *Journal of Guidance, Control and Dynamics*, Vol. 24, No.1, 2001, pp.131-133.

Fahroo, F. and Ross, I.M., "Costate Estimation by a Legendre Pseudospectral Method," *Journal of Guidance, Control and Dynamics*, accepted for publication in FY 2000, appeared in Vol. 24, No. 2, 2001, pp. 270-277.

Fahroo, F. and Ross, I.M., "Direct Trajectory Optimization by a Chebyshev Pseudospectral Method," accepted for publication in the *Journal of Guidance, Control and Dynamics*.

Yan, H., Fahroo, F. and Ross, I.M., "Accuracy and Optimality of Direct Transcription Methods," *Advances in the Astronautical Sciences, Space Flight Mechanics 2000*, Vol. 105, Part II, pp.1601-1630, (Kluver, C. A. et al, eds.), AAS Paper No. 00-205.

Fahroo, F. and Ross, I.M., "A Spectral Patching Method for Direct Trajectory Optimization," to appear in a Special Issue of the *Advances in the Astronautical Sciences* (AAS 00-260).

PROJECT SUMMARIES

PRESENTATIONS:

Fahroo, F. and Ross, I.M., "Spectral Collocation Approximations for Optimal Control Problems," AMS Southeastern Section Conference (Special Session, Invited Talk), Lafayette, LA, 14-16 April 2000.

Fahroo, F. and Ross, I.M., "Direct Trajectory Optimization by a Chebyshev Pseudospectral Method," *Proceedings of the American Control Conference*, June 2000, Chicago, IL, Paper ACC00-AIAA1004.

Fahroo, F. and Ross, I.M., "Trajectory Optimization by Indirect Spectral Collocation Methods," *Proceedings of the AIAA/AAS Astrodynamics Specialist Conference*, August 2000, Denver, CO.

THESIS DIRECTED:

Schlotman, B., "Feasibility of Two-Gimbal Platform Tumbling to Minimize Velocity Error," Masters Thesis, Naval Postgraduate School, June 2000.

ADVANCED FAN AND COMPRESSOR DEVELOPMENT STUDIES

R. P. Shreeve, Professor

G. V. Hobson, Associate Professor

Department of Aeronautics and Astronautics

Sponsor: Naval Air Warfare Center-Aircraft Division

OBJECTIVE: To develop or validate tools for the design of advanced compression systems for Navy engines. Four tasks are ongoing: (i) to obtain experimental measurements and observations of CD blade stall for CFD code validation; (ii) to develop a geometry package geared to the design (by CFD analysis) of swept transonic blading, and to facilitate design optimization; (iii) to install and test an advanced transonic axial stage, and thereby establish the means to evaluate more advanced designs economically; (iv) to develop advanced measurement capability.

SUMMARY: (i) Blade-to-blade five-hole pressure probe surveys were made at different span-wise locations, to obtain the loss behavior of second-generation CD blading, at four degrees above design incidence. LDV was used to map the velocity field, and three-dimensional viscous flow calculations were made of the complete (periodic) passage flow. (ii) A new Bezier-surface representation of axial transonic blading, requiring only 32 control points and two parameters, was developed in an earlier Ph.D. study. Forward and aft sweep were introduced into a rotor design without changing blade shape, and the effect on aerodynamic performance and rotational stresses were determined. The geometry package was used successfully by a second student to perform a (limited) airfoil design optimization. A (limited) rotor design optimization can now be attempted. (iii) The Sanger (code-validation) compressor stage was rebuilt, re-instrumented and retested using a UV-transparent case wall. The need to control tip-clearance gap, and a method to do it, were demonstrated in a very successful test program. (iv) Development of pressure sensitive paint techniques for rotor measurements required the construction of a bench-top apparatus, with which to calibrate for pressure and temperature dependence over the ranges of interest. Application to the Sanger rotor test will follow the construction of an aluminum and Plexiglas modular case wall. A tip-timing technique for measuring the vibrations of rotor blades using laser light probes, was set up and validated (vs. photo observations), on a three-stage low speed compressor. This 'NSMS' technique was also required for blade response measurements in the HCF/Spin Test Research program.

PUBLICATION:

Hobson, G.V., Hansen, D.J., Schnorenberg, D.G., and Grove, D.V., "Effect of Reynolds Number on Separation Bubbles on Controlled-Diffusion Compressor Blades in Cascade," *Journal of Propulsion and Power*, Vol. 40, No. 1, January-February 2001, pp. 154-162.

PROJECT SUMMARIES

PRESENTATIONS:

Enomoto, S., Hah, C., and Hobson, G.V., "Numerical and Experimental Investigation of Low Reynolds Number Effects on Laminar Flow Separation and Transition in a Cascade of Compressor Blades," Paper 2000-GT-0276, presented at the ASME Turbo Expo 2000, Munich, Germany, 8-11 May 2000.

Hobson G.V. and Weber, S., "Prediction of a Laminar Separation Bubble Over a Controlled-Diffusion Compressor Blade," Paper 2000-GT-0277, presented at the ASME Turbo Expo 2000, Munich, Germany, 8-11 May 2000.

von Backstrom, T.W., Hobson, G.V., Grossman, B., and Shreeve, R.P., "Investigation of the Performance of a CFD Designed Compressor Stage," Paper AIAA 2000-3205, presented at the 36th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Huntsville, AL, 17-19 July 2000.

THESES DIRECTED:

Muller, J.A., "Calibration to Determine Pressure and Temperature Sensitivities of a Pressure-Sensitive Paint," Masters Thesis, Naval Postgraduate School, June 2000.

O'Brian, J.M., "Transonic Compressor Test Rig Rebuild and Initial Results with the Sanger Stage," Masters Thesis, Naval Postgraduate School, June 2000.

Osburn, N.G., "Implementation of a Two-Probe Tip-Timing Technique to Determine Compressor Blade Vibrations," Masters Thesis, Naval Postgraduate School, June 2000.

Carlson, J.R., "Experimental and Computational Investigation of the End-Wall Flow in a Cascade of Compressor Blades," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Controlled-Diffusion Blading, LDV Measurements, Compressor Cascade Stall, Transonic Compressor Design, Pressure-Sensitive Paint (PSP)

HCF/SPIN TEST RESEARCH

R. P. Shreeve, Professor

G. V. Hobson, Associate Professor

Department of Aeronautics and Astronautics

Sponsor: Naval Air Warfare Center-Aircraft Division and Naval Postgraduate School

OBJECTIVE: To investigate techniques for producing controlled blade excitation and measuring blade response which are suitable for high cycle fatigue (HCF)-related spin-testing and, when appropriate, to help transition those techniques to the Navy's Rotary Spin Facility at NAWCAD; also, to explore other HCF research opportunities.

SUMMARY: The engine-scale spin pit at the Turbopropulsion Laboratory was refurbished to serve as a research facility for the development of HCF-related gas-turbine rotor test and evaluation techniques. After initial tests using a large M1 rocket motor turbine rotor, blade excitation methods were explored using two (low cost, low risk) eleven-inch diameter rotors. First, air-jet excitation (AJE) and eddy-current excitation (ECE) were used to excite resonant modes at 3E (engine order) and 12E in an aluminum research fan. Second, ECE and oil-jet excitation (OJE) were used at 6E (and OJE at 4E) in a cropped titanium fan rotor. Hardware, and software acquisition and analysis programs were progressively developed for a twelve-channel strain gauge system and a four-channel tip-timing ('NSMS') system using capacitive or eddy-current probes. (A two-channel NSMS system using laser-light probes was separately demonstrated on a low-speed compressor). In collaboration with NAVAIR and Pratt & Whitney, the first engine-scale spin pit

PROJECT SUMMARIES

tests will evaluate internal dampers for JSF engine-type counter-rotating turbine rotors, and resonant behavior of an F119 engine fan blisk. The excitation work has been carried out in collaboration with Hood Technology Corporation, who is funded by the Air Force to evaluate ECE.

PRESENTATIONS:

Shreeve, R.P., "HCF/Spin Test Research Review," Navy/Air Force Joint Program Review, Monterey, CA 19 May 2000.

Warren, J. and Shreeve, R.P., "The Navy's HCF Spin Test Program," HCF Passive Damping Action Team Meeting, Duke University, Durham, NC, 8 August 2000.

THESIS DIRECTED:

Osburn, N.G., "Implementation of a Two-Probe Tip-Timing Technique to Determine Compressor Blade Vibrations," Master Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Spin Testing, High Cycle Fatigue, Gas Turbine Blade Excitation

SATELLITE SERVICING LABORATORY

Michael G. Spencer, Assistant Professor

Department of Aeronautics and Astronautics

Sponsor: Naval Postgraduate School Research Initiation Program

OBJECTIVE: The objective of this research is to develop an autonomous servicing spacecraft simulator and test-bed. The simulator will be used for the development and validation of autonomous, neural network based control algorithms as well as various hardware elements necessary for autonomous rendezvous and docking, space manipulator control, and satellite servicing operations.

SUMMARY: The background research and scope of the new effort was developed during the initial three months of employment (September – November 00). The research proposal was approved mid December therefore, the significant efforts of this research will continue into 2001.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Satellite Servicing

RESEARCH IN THE STRUCTURAL DYNAMIC RESPONSE OF THE RAH-66 COMANCHE HELICOPTER

E. Roberts Wood, Professor

Department of Aeronautics and Astronautics

Sponsor: U.S. Army Comanche Program Office

OBJECTIVE: Continued work in support of the ongoing development of the Army's RAH-66 Comanche Helicopter. Tasks include static and dynamic analyses. A dynamic NASTRAN model provides the basis for the analyses and is maintained at the Naval Postgraduate School to support the ongoing Comanche flight test development program. The objective of the analyses is the optimization of the airframe for dynamic response.

DoD KEY TECHNOLOGY AREAS: Computing and Software

PROJECT SUMMARIES

KEYWORDS: Helicopter, Rotorcraft, Dynamics, Structures, NASTRAN

IMPROVED TARGET ACCURACY AND SENSOR AIMING FOR RAH-66 WEAPONS SYSTEM

E. Roberts Wood, Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: Using the MSC/NASTRAN structural dynamic model of the RAH-66 helicopter, determine biases between sensor loss and weapon pointing to the target for specified conditions as a function of the flight envelope. Biases are to be applied as fire control corrections. Weapons of interest are 2.75-in., rockets, stinger air-to-air wing-mounted missiles and three-barrel, nose mounted 20-mm turreted Gatling gun. Sensors include FCR, TV, and FLIR.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Helicopter, Rotorcraft Dynamics, Structures, NASTRAN

RESEARCH IN DAMPER FREE ROTOR DESIGN BASED ON MAPLE GENERATED NONLINEAR SIMULATION

E. Roberts Wood, Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: Derive the full non-linear lead-lag equations of motion for a multiblade helicopter rotor. Incorporate MAPLE and SIMULINK in the derivation. Apply this new expanded analysis in two areas with high potential for eliminating reliance on mechanical damping in helicopters. These are by introduction of structural tailoring to provide non-linear hinge less rotor lead/lag characteristics; and by swash plate feedback for increased lead/lag stability.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Rotorcraft, Helicopter, Ground/Air Resonance, Damperless, VTOL/MAPLE/SIMULIN

**DEPARTMENT OF
AERONAUTICS AND
ASTRONAUTICS**

**Faculty Publications
and Presentations**

PUBLICATIONS/PRESENTATIONS

JOURNAL PAPERS

Fahroo, F. and Ross, I.M., "A Spectral Patching Method for Direct Trajectory Optimization," *The Journal of the Astronautical Sciences*, Vol. 48, No. 2/3, April-September 2000.

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Pascoal, M., Kaminer, I.I., and Oliveira, P., "Design of the Complementary, Time-Varying Filters Using Linear Matrix Inequalities," *IEEE Transactions on Aerospace and Electronics*, Vol. 36, No. 4, pp. 1099-1114.

Song, G., Kelly, B., and Agrawal, B.N., "Active Position Control of a Shape Memory Alloy Wire Actuated Composite Beam," *Journal of Smart Materials and Structures*, Vol. 9, 2000, pp. 711-716.

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Varnes, D.J., Duren, R.W., and Wood, E.R., "Detecting the Vortex Ring State," *Rotor & Wing*, Vol. 34, No. 1, pp. 60-65, January 2000.

Weber, S. and Platzer, M.F., "Computational Simulation of Dynamic Stall on the NLR 7301 Airfoil," *Journal of Fluids and Structures*, Vol. 14, pp. 779-798, 2000.

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Yan, H., Fahroo, F. and Ross, I.M., "Accuracy and Optimality of Direct Transcription Methods," *Advances in the Astronautical Sciences, Space Flight Mechanics 2000*, Vol. 105, Part II, pp.1601-1630, (Kluwer, C. A. et al., eds.), AAS Paper No. 00-205.

CONFERENCE PAPERS

Agrawal, B. and Chen, H.J. "Active Vibration Isolation on Spacecraft Using Smart Struts," IAF-00.I.4.05 51 International Astronautical Congress, 2-6 Oct 2000, Rio de Janeiro, Brazil.

Bernelli-Zazzera, F., Romano, M., and Agrawal, B., "Experiments on Tracking Control of a Flexible Space Manipulators," IAF-00-A.3.05, International Astronautical Congress, 2-6 October 2000, Rio de Janeiro, Brazil.

Brophy, C.M. and Sinibaldi, J., "Operation of a JP10/Air Pulse Detonation Engine," 36th Joint Propulsion Conference, AIAA 2000-3591, Huntsville, AL, 2000.

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PUBLICATIONS/PRESENTATIONS

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Castro, B.M., Ekaterinaris, J.A., and Platzer, M.F., "Transonic Flutter Computations for the NLR 7301 Airfoil inside a Wind Tunnel," AIAA Paper 2000-0984, 38th Aerospace Sciences Meeting, Reno, NV, 10-13 January 2000.

Dellicker, S., Williams, T., Hewgley, C., Yakimenko, O., Howard, R., Kaminer, I.I., Benney, R., and Patel, S., "Performance, Control, and Simulation of the Affordable Guided Airdrop System," *Proceedings 2000 AIAA Conference on Guidance, Navigation and Control*, Denver, CO, August 2000.

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Hobson, G.V., Anderson, S.C., McKee, J. and Southward, J., "Experimental and Numerical Investigation of the Tip Leakage Flow in the Single Stage Turbine of the Space Shuttle Turbopump," AIAA-2001-0831 39th AIAA Aerospace Sciences Conference, Reno, NV, January 2001.

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Venner, M.J., Johnson, C.W., and Brophy, C.M., "Signature Characterization of a Small Liquid Rocket Engine Burning Various Kerosene-Based Fuels," *Military Sensing Symposia*, MD-SEA, SPAWAR Systems Center, Charleston, SC, 25-27 January 2000.

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Weber, S. and Platzter, M.F., "A Navier-Stokes Analysis of the Stall Flutter Characteristics of the Buffum Cascade," ASME Paper No. 2000-GT-385, International Gas Turbine Congress, Munich, Germany, 8-11 May 2000.

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CONFERENCE PRESENTATIONS

Agrawal, B. and Chen, H.J. "Active Vibration Isolation on Spacecraft Using Smart Struts," 51st International Astronautical Congress, Rio de Janeiro, Brazil, 2-6 October 2000.

Bernelli-Zazzera, F., Romano, M., and Agrawal, B., "Experiments on Tracking Control of a Flexible Space Manipulators," presented at 51st International Astronautical Congress, 2-6 October 2000, Rio de Janeiro, Brazil.

Brophy, C.M., et. al., "Detonation of a JP-10/Aerosol for Pulse Detonation Applications," International Colloquium on the Control of Detonation Processes, Moscow, 4-7 July 2000.

Brophy, C.M., Scruton, Z.M., and Johnson, C.W., "Measurements of Fuel Additive Effects on the Soot Mass Loading in Oxygen/Kerosene Exhaust Plumes," 2000 JANNAF Exhaust Plume Technology Subcommittee, Las Vegas, NV, 15-19 May 2000.

Duren, R.W., Wood, E.R., and Couch, M.A., "NPS Vortex Ring State Definition and Safety Data Review," Rotorcraft Aeromechanics Workshop, Naval Air Systems Command, Patuxent River, MD, 18-19 July 2000.

Enomoto, S., Hah, C., and Hobson, G.V., "Numerical and Experimental Investigation of Low Reynolds Number Effects on Laminar Flow Separation and Transition in a Cascade of Compressor Blades," 2000-GT-0276, ASME Turbo Expo 2000, Munich, Germany, June 2000.

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Jones, K. D., Lund, T. C., and Platzter, M. F., "Experimental and Computational Investigation of Flapping-Wing Propulsion for Micro-Air Vehicles," Conference on Fixed, Flapping and Rotary Wing Vehicles at Very Low Reynolds Numbers, University of Notre Dame, Notre Dame, IN, 5-7 June 2000.

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Platzer, M.F. and Jones, K.D., "The Unsteady Aerodynamics of Flapping -Foil Propellers," Ninth International Symposium on Unsteady Aerodynamics and Aeroelasticity of Turbomachines, Lyon, France, 5-8 September 2000.

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Sinibaldi, J., Brophy, C.M., and Robinson, J., "Ignition Effects on Deflagration-to-Detonation Transition in Gaseous Mixtures," 36th Joint Propulsion Conference, AIAA 2000-3590, Huntsville, AL, 2000.

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von Backstrom, T.W., Hobson, G.V., Grossman, B., and Shreeve, R.P., "Numerical Analysis of a CFD Designed Compressor Stage," AIAA-2000-3205, ASME/AIAA/SAE Joint Propulsion Conference, June 2000.

Warren, J. and Shreeve, R.P., "The Navy's HCF Spin Test Program," HCF Passive Damping Action Team Meeting, Duke University, Durham, NC, 8 August 2000.

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**DEPARTMENT OF
AERONAUTICS AND
ASTRONAUTICS**

Thesis Abstracts

THESIS ABSTRACTS

DEVELOPMENT OF SHROUDED TURBOJET TO FORM A TURBORAMJET FOR FUTURE MISSILE APPLICATIONS

Suleiman M. al-Namani-Captain, Royal Army of Oman

B.Eng., Staffordshire University, 1992

Master of Science in Applied Physics-June 2000

Advisors: Garth V. Hobson, Department of Aeronautics and Astronautics

Karlheinz E. Woehler, Professor Emeritus

Development of a shroud to form part of an afterburner for a turbo-ramjet engine which has a possible application for high speed long range missile applications. Research has been conducted on scram-jet engines with little or no emphasis on turbojet/ramjet combined cycle engines. With the possibility of the turbojet providing the thrust at subsonic conditions and the ramjet providing the thrust at supersonic conditions. A small turbojet engine, the Sophia J450, was evaluated experimentally and the results were compared to the prediction using an industry standard program with a perfect comparison over a wide operating range. In order to study possible turbo-ramjet configurations, a Sophia J450 turbojet engine was used with various shroud configurations, to compare static thrust and specific fuel consumption measured in a test rig. Shroud pressures were also recorded to determine the entrainment rate of the ducts. The short shroud results were found to produce the best performance of the three configurations tested. The performance improvements were more significant at lower engine spool speeds that produced a sharp increase in secondary entrainment pressure.

A conical supersonic intake was designed for combined cycle engine at a Mach 2 flight condition resulting in a near optimum cone angle of 15 (deg) to be tested in the new free jet facility. The flight envelope of the baseline engine was also determined over a wide range of flight speeds and operating altitudes.

DOD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Micro-Turbojet, GASTURB, Engine Shroud, Turboramjet, Sophia J450, Microturbine Performance

PERFORMANCE AND SPACE BORNE APPLICATION ANALYSIS OF THE HIGHER ORDER CYCLOSTATIONARY BASED CLASSIFIER

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Master of Science in Astronautical Engineering-December 2000

Advisors: Brij N. Agrawal, Department of Aeronautics and Astronautics

Charles W. Therrien, Department of Electrical and Computer Engineering

Second Reader: Tri T. Ha, Department of Electrical and Computer Engineering

Testing of the Higher Order Cyclostationary Based Classifier (HBC) is conducted to evaluate system operational performance. Utilizing Higher Order Cyclostationary (HOCS) analysis techniques, the HBC is designed to automatically detect and classify communication and radar signals contained in input signal samples. While test results utilizing earlier data were inconclusive on the effectiveness of the system, a more rigorous testing for Binary Phase-Shift Keying (BPSK) modulation scheme is herein carried out. The results of the HBC analysis reveal a system which experiences difficulty in performing modulation detection and classification of the input data at signal-to-noise ratios above 10 dB. The HBC automatic band-of-interest detector also shows evidence of interfering with accurate signal classification results. Recommended improvements to the algorithms and interface are presented to address these and other observed trends. An application of the HBC system to the Naval Research Laboratory's Pre-Configured Interface Payload (PCIP) program are assessed for space borne testing of the HBC system.

DOD KEY TECHNOLOGY AREAS: Space Vehicles, Computing and Software, Sensors, Modeling and Simulation

THESIS ABSTRACTS

KEYWORDS: Cyclostationary, Digital Signals, Signal Classification, SignalIntelligence (SIGINT), Spacecraft Payload Integration, Pre-Configured Interface Payload (PCIP)

ADAPTIVE MULTI-LAYER LMS CONTROLLER DESIGN AND ITS APPLICATION TO ACTIVE VIBRATION SUPPRESSION ON A SPACE TRUSS

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B.S., Eastern Michigan University, 1993

Master of Science in Mechanical Engineering-June 2001

Advisors: Young S. Shin, Department of Mechanical Engineering

Brij N. Agrawal, Department of Aeronautics and Astronautics

This thesis develops an adaptive controller that actively suppresses a single frequency disturbance source at a remote position and tests the system on the NPS Space Truss. The experimental results are then compared to those predicted by an ANSYS finite element model. The NPS space truss is a 3.7-meter long truss that simulates a space-borne appendage with sensitive equipment mounted at its extremities. One of two installed piezoelectric actuators and an Adaptive Multi-Layer LMS control law were used to effectively eliminate an axial component of the vibrations induced by a linear proof mass actuator mounted at one end of the truss. Experimental and analytical results both demonstrate reductions to the level of system noise. Vibration reductions in excess of 50dB were obtained through experimentation and over 100dB using ANSYS, demonstrating the ability to model this system with a finite element model. This thesis also proposes a method to use distributed quartz accelerometers to evaluate the location, direction, and energy of impacts on the NPS space truss using the dSPACE data acquisition and processing system to capture the structural response and compare it to known reference signals.

DOD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation

KEYWORDS: Active Vibration Suppression, Piezoceramic Actuators, Impact Analysis, Adaptive Controller, LMS

TIME DOMAIN VALIDATION OF THE SIKORSKY GENERAL HELICOPTER (GENHEL) FLIGHT DYNAMICS SIMULATION MODEL FOR THE UH-60L WIDE CHORD BLADE MODIFICATION

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Master of Science in Aeronautical Engineering-December 1999

Advisors: E. Roberts Wood, Department of Aeronautics and Astronautics

Thomas H. Lawrence, Sikorsky Aircraft Corporation

Helicopter design at the Sikorsky Aircraft Corporation is aided by the use of the Sikorsky General Helicopter (GenHel®) Flight Dynamics Simulation Model. Specifically, GenHel output is used by both handling qualities and maneuver loads engineers as a predictive design tool. Inherent in the use of an analytical model is the requirement for validation. This report seeks to validate the GenHel® flight dynamics simulation models used in the design of the UH-60L Wide Chord Blade (WCB) modification. Initially, comparisons are made between the current analytical models and flight test data for selected trim flight conditions and dynamic maneuvers. Based on the correlation of the data, modifications are made to the analytical model where necessary. The modified analytical model will be validated through a final comparison with test flight data. The goal of this report is to validate the use of Sikorsky's GenHel® flight simulation program as an analytic predictive tool in the design of the WCB modification and identify any areas where improvements could be applied. Validation of the WCB GenHel model serves two purposes. First it confirms the ability of GenHel to model the flight dynamic response of the UH-60L with the WCB

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modification. Second it confirms the predictive loads forwarded to the structural engineers during the design phase of the WCB.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: Helicopter Dynamics, Mathematical Modeling

EXPERIMENTAL AND COMPUTATIONAL INVESTIGATION OF THE ENDWALL FLOW IN A CASCADE OF COMPRESOR BLADES

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Master of Science in Aeronautical Engineering-September 2000

Advisor: Garth V. Hobson, Department of Aeronautics and Astronautics

Second Reader: Raymond P. Shreeve, Department of Aeronautics and Astronautics

An investigation of the three-dimensional flow in a cascade of second-generation controlled-diffusion blades, which was a result of the interaction of the endwall boundary layers with the blade profiles, is reported. Five-hole probe wake surveys were performed at various spanwise locations to determine the total pressure loss distribution. Downstream velocity vector information was also obtained from the five-hole probe surveys. Two-component laser-Doppler velocimetry (LDV) was used to characterize the flow in the inlet and wake regions. A numerical investigation of the flowfield was conducted using SWIFT, a computational fluid dynamics code developed by Dr. Roderick Chima of NASA Glenn Research Center. Experimental blade-surface pressure coefficients were compared with values predicted using SWIFT. Overall, good correlation between the five-hole probe and LDV measurement techniques was obtained; however, the CFD predictions did not match well with the experimental results, particularly at the midspan location of the blade where separation of the suction surface boundary layer occurred.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Laser Doppler Velocimetry, Controlled-Diffusion Compressor Blading

OPTIMIZATION PROCEDURE FOR ELECTRIC PROPULSION ENGINES

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Master of Science in Applied Physics-December 1999

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James H. Luscombe, Department of Physics

This thesis addresses the optimization of all types of space electrical propulsion thrusters. From the Langmuir-Irving payload mass fraction formulation, a "dual-optimum" solution is defined, yielding a minimum overall mass for a specified payload consistent with minimum transfer time. This solution fixes the ideal payload mass ratio (m_{pl} / m_o) at a value of 0.45, establishing the ratios of effective exhaust velocity (v / v_c) and incremental change of vehicle velocity ($\Delta u / v_c$) to characteristic velocity at 0.820 and 0.327 respectively. The characteristic velocity (v_c) includes thrust time as well as engine efficiency (η_l) and specific power (α). A range of mass ratios from 0.35 to 0.55 is used in order to allow the system designer some flexibility while remaining close to optimal. Nine examples are presented which demonstrate that mission profiles can be optimized by profile-to-thruster matching. A comprehensive list of currently available electric propulsion engines is provided. This list details important parameters such as the specific power, which "sizes" an engine in terms of power provided to the thruster at the cost of additional mass. Allowance is also made for a fuel tank mass penalty, and examples show that this can also noticeably influence the optimum design.

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DOD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Space Vehicles

KEYWORDS: Space Propulsion, Electric Propulsion, Ion Engines, Hall Thrusters, Optimum Specific Impulse, Minimum Thrusting Time

INCORPORATION OF ENHANCED GROUND PROXIMITY WARNING SYSTEM (EGPWS) IN THE NASA AMES RESEARCH CENTER CAE BOEING 747-400 FLIGHT SIMULATOR

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Master of Science in Aeronautical Engineering-September 2000

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Second Reader: Oleg A. Yakimenko, National Research Council Senior Research Associate

The NASA Ames Research Center CAE Boeing 747-400 flight simulator is used primarily for the study of human factors in aviation safety. The simulator is constantly upgraded to maintain a configuration match to a specific United Airlines aircraft and maintains the highest level of FAA certification to ensure credibility to the results of research programs. United's 747-400 fleet, and hence the simulator, are transitioning from the older Ground Proximity Warning System (GPWS) to the state-of-the-art Enhanced Ground Proximity Warning System (EGPWS). GPWS was an early attempt to reduce or eliminate Controlled Flight Into Terrain (CFIT). Basic GPWS alerting modes include: excessive descent rate, excessive terrain closure rate, altitude loss after takeoff, unsafe terrain clearance, excessive deviation below glideslope, advisory callouts and windshear alerting. However, since GPWS uses the radar altimeter which looks straight down, ample warning is not always provided. EGPWS retains all of the basic functions of GPWS but adds the ability to "look ahead" by comparing the aircraft position to an internal database and provide additional alerting and display capabilities. This thesis evaluates three methods of incorporating EGPWS in the simulator and describes the implementation and architecture of the preferred option.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Enhanced Ground Proximity Warning System, Ground Proximity Warning System, Controlled Flight Into Terrain, Terrain Alerting and Display, Terrain Clearance Floor, Flight Simulator, NASA

COMPUTATIONAL FLUID DYNAMICS PREDICTION OF SUBSONIC AXIS-SYMMETRIC AND TWO-DIMENSIONAL HEATED FREE TURBULENT AIR JETS

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Mechanical Engineer-September 2000

Master of Science in Mechanical Engineering-September 2000

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A study was conducted to evaluate the accuracy of a commercial computational fluid dynamics (CFD) code (CFDRC-ACE+) for predicting incompressible air jet flows with simple geometrics. Specifically, the axis-symmetric and two-dimensional heated air-jets were simulated using a standard $k-\epsilon$ turbulence model. These CFD predictions were directly compared to an extensive compilation of experimental data from archive literature. The round jet results indicated that the code over-predicted the velocity-spreading rate by 24% and the temperature-spreading rate by 29%. In addition, the centerline velocity and temperature decay rates were also over-predicted, as well, by approximately 7.5 diameters for the velocity profiles and 10.5 diameters for the temperature profiles. The planar jet simulation was generally closer to experimental

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data ranges, with an under-prediction of the velocity-spreading rate of approximately 17% with an over-predicted temperature spreading rate of 12%. The centerline velocity and temperature decay rates were both under-predicted at 22% and 27% respectively. Again, the geometric and kinematic virtual origins were over-predicted by approximately 7.5 slot heights for the velocity profiles and 10.5 slot heights for the temperature profiles.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Computational Fluid Dynamics (CFD), Eductor, Ejector, Gas Turbine, Exhaust, Axisymmetric Jet, Two-Dimensional Jet, Air Jet, Free Turbulent, Jet

AN EXPERIMENTAL INVESTIGATION OF FLAPPING WING PROPULSION FOR MICRO AIR VEHICLES

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Max F. Platzer, Department of Aeronautics and Astronautics

Flapping-wing propulsion is studied experimentally through thrust measurements and flow visualization. The objective of the research is to provide further insight into the aerodynamics of flapping-wing micro air vehicles (MAVs). Experimental work is conducted in the NPS 1.5 m x 1.5 m in-depth wind tunnel. A previously constructed model is suspended by thin wires and is used to measure the thrust performance of the flapping-wing MAV. For this experiment, the model is tested in four configurations; three with varying wing mount stiffness and the fourth with an articulated pitch mechanism. Thrust is indirectly determined using a laser range-finder to measure stream-wise displacement of the model. Three methods of flow visualization are attempted to gain further insight into the flow-field around the MAV. First tufts are placed on and around the model to identify the flow-field. Second, a smoke rake placed outside the tunnel is used to route smoke into the test section. Thirdly, a smoke wire system is used to produce smoke in the test section. Experimental results are compared with flow visualization results and previous experimental and numerical work.

DOD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Other (Micro Air Vehicles)

KEYWORDS: Flapping Wing, Micro Air Vehicle, Low Reynolds Number, Flow Visibility

TESTING AND DEVELOPMENT OF A SHROUDED GAS TURBINE ENGINE IN A FREEJET FACILITY

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Karlheinz E. Woehler, Professor Emeritus

Testing and analysis of a shrouded turbojet engine with possible application for high speed propulsion on low cost Unmanned Combat Aerial Vehicles (UCAV), Unmanned Aerial Vehicles (UAV) and missiles was the subject of this thesis. The possibility of a turbojet providing thrust at subsonic conditions and the ramjet section providing the thrust in a supersonic regime exists. The combined cycle engine (CCE) could be incorporated into a variety of applications.

The building of new freejet facility and engine test rig at the Naval Postgraduate School enabled dynamic testing of the ongoing development of a turboramjet. The freejet facility and new engine stand performed without exception. The shrouded engine was dynamically tested in a freejet up to Mach 0.4.

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The engine performance measurements closely matched those predicted by a cycle analysis program, GASTURB.

Computational fluid dynamics (CFD) was used to analyze the supersonic inlet at a design point of Mach 2. The results provided by the CFD code, OVERFLOW, matched theoretical flow parameters. The intake design was slightly modified to enhance performance of shock waves in the supersonic flight regime.

DOD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Micro-Turbojet, GASTURB, Engine Shroud, Turboramjet, Sophia J450, Microturbine

VISION-BASED NAVIGATION FOR AUTONOMOUS LANDING OF UNMANNED AERIAL VEHICLES

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Aeronautical and Astronautical Engineering-September 2000

**Advisors: Isaac I. Kaminer, Department of Aeronautics and Astronautics
Oleg A. Yakimenko, National Research Council Senior Research Associate**

The role of Unmanned Aerial Vehicles (UAVs) for modern military operations is expected to expand in the 21st Century, including increased deployment of UAVs from Navy ships at sea. Autonomous operation of UAVs from ships at sea requires the UAV to land on a moving ship using only passive sensors installed in the UAV to estimate the UAV position relative to the moving platform. A navigation algorithm based on photogrammetry and perspective estimation is presented for numerically determining the relative position and orientation of an aircraft with respect to a ship that possesses three visibly significant points with known separation distances. Original image processing algorithms that reliably locate visually significant features in monochrome images are developed. Monochrome video imagery collected during flight test with an infrared video camera mounted in the nose of a UAV during actual landing approaches is presented. The navigation and image processing algorithms are combined to reduce the flight test images into vehicle position estimates. These position estimates are compared to truth data to demonstrate the feasibility of passive, vision-based sensors for aircraft navigation. Conclusions are drawn, and recommendations for further study are presented.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Sensors

KEYWORDS: Unmanned Aerial Vehicle, Navigation, Infrared Imaging, Image-Processing, MATLAB®, Simulation

INVESTIGATION OF CROSS FLOW FAN PROPULSION FOR LIGHTWEIGHT VTOL AIRCRAFT

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Master of Science in Aeronautical Engineering-December 2000**

**Advisors: Max F. Platzler, Department of Aeronautics and Astronautics
Kevin D. Jones, Department of Aeronautics and Astronautics**

As world population increases, road and airport congestion will become increasingly prevalent. A small, cheap VTOL aircraft which can be flown from a driveway to the workplace parking lot would reduce traffic congestion and travel time. A lightweight, single seat commuter type VTOL aircraft is envisioned as the solution to this problem. To achieve a goal of minimum weight, the aircraft aerodynamic design should be optimized for forward flight. Vertical thrust augmentation from a propulsion unit contained within the fuselage would have little detriment to forward flight aerodynamics, and the cross flow fan can be accommodated as such. Cross flow fan propulsion has not been seriously considered for aircraft use since

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an LTV Vought Systems Division study for the U.S. Navy in 1975. Despite an indepth knowledge of the design parameters and airflow relationships in cross flow fans, the existing data supports the hypothesis that with further development the thrust efficiency and thrust-to-weight ratio could improve to the point where this thrust producing method is viable. This study investigates the incorporation of rotary engine powered cross flow fan propulsion in a hypothetical lightweight VTOL aircraft and concludes that cross flow fan propulsion is viable but only with further investigation of power plant technology and fan design parameters and relationships.

DOD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: VTOL, Cross Flow Fan, Ducted Propeller

A NUMERICAL STUDY OF FUEL-OPTIMAL LOW-EARTH ORBIT MAINTENANCE

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Master of Science in Astronautical Engineering-December 2000

Advisors: I.M. Ross, Department of Aeronautics and Astronautics

Fariba Fahroo, Department of Mathematics

This thesis studies the fuel optimal periodic reboost profile required to maintain a spacecraft experiencing drag in low-earth-orbit (LEO). Recent advances in computational optimal control theory are employed, along with a Legendre-Gauss-Lobatto Pseudospectral collocation code developed at the Naval Postgraduate School, to solve the problem. Solutions obtained by this method are compared against a previous study. Key issues were checking the optimality of the solutions by way of the necessary conditions and the behavior of the solution to changes in the thruster size. The results confirmed Jensen's findings of propellant savings of one to five percent when compared against a middle altitude Force Keplerian Trajectory (FKT). Larger savings are predicted if compared against a finite-burn Hohmann transfer with drag. The costates estimates compared favorable against necessary conditions of Pontryagin's Minimum Principle. Analysis of the switching function yielded period of thrust-modulated arcs. The optimal thrust profile appears to be a thrust-modulated burn to raise the orbit followed by an orbital decay and a terminating thrust-modulated arc. For a sufficiently low thrust-control authority, the switching structure includes a maximum thrust arc. Indirect optimization techniques to confirm these findings were unsuccessful.

DOD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Orbital Mechanics, Optimization, Optimal Control Theory, Orbit Maintenance

TELEMETRY SYSTEMS ANALYSIS AND DESIGN

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Second Reader: Norm Sorensen, National Reconnaissance Office Chair Professor

The Navy has a valuable opportunity to improve its own products and operations efficiency by showing its future leaders and designers how to design effective and viable telemetry, tracking, and commanding (TT&C) systems, and their operation. One system is the FLTSTAT military communications constellation of spacecraft, one of which has been a static display at the Naval Postgraduate School (NPS) until June, 2000. The primary objective was to make this spacecraft operational and thus provide a new operational spacecraft laboratory for other NPS students. This thesis may also be used as a primer for the space engineering or space operations student regarding TT&C system design. Great effort has been taken to

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document and discuss current design practices and standards adopted by DoD laboratories, test facilities and operation centers. A TT&C system designed for a spacecraft incorporating all the traditional subsystems (payload, thermal, structural, power, TT&C, attitude control) is included.

DOD KEY TECHNOLOGY AREAS: Space Vehicles, Other (Communications)

KEYWORDS: Space Vehicles, Communications

EXPLORATION OF FIBRE CHANNEL AS AN AVIONICS INTERCONNECT FOR THE 21ST CENTURY MILITARY AIRCRAFT

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Aeronautical and Astronautical Engineer-September 2000

Master of Science in Aeronautical Engineering-September 2000

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Second Reader: John C. McEachen, Department of Electrical and Computer Engineering

Avionics architects are evolving from "Federated" systems consisting of highly specialized black boxes connected together via MIL-STD-1553 and ARINC 429 data buses to "Integrate" and "Distributed" architectures. These new architectures contain high data-rate sensors, parallel processors, and shared memory with high levels of integration. These systems require a new interconnection system that overcomes the limitations of older standards. One such interconnection system is Fibre Channel. This thesis evaluates Fibre Channel as avionics interconnection standard. It begins by defining the requirements and measures of performance for an interconnection system suitable for the new avionics architectures. The requirements address technical performance, affordability, reliability, sustainability, and maintainability considerations. The Fibre Channel standards are then compared to the requirements for the avionics interconnection system. In order to perform a technical performance evaluation of a switched fabric avionics interconnection system, a computer simulation model was developed. The OPNET Modeler® tool from OPNET, Inc. was used to model the components of an advanced avionics system. The results of this simulation demonstrated that Fibre Channel meets all the performance requirements of an avionics interconnect.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Electronics, Modeling and Simulation

KEYWORDS: Fibre Channel, Interconnect, Avionics, Bandwidth, Modeling, Simulation

PROPAGATION OF A TWO-PHASE DETONATION ACROSS A GEOMETRIC DIFFRACTION WITH COMPOSITIONAL DISCONTINUITY

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David W. Netzer, Department of Aeronautics and Astronautics

Raymond P. Shreeve, Department of Aeronautics and Astronautics

The research program involved the modification and use of an existing pulse detonation engine (PDE) to investigate the detonability of a JP-10/air aerosol. The detonation of a JP-10 aerosol in air proved more difficult than was originally anticipated.

The use of a small JP-10/oxygen pre-detonator to provide direct initiation results in a transition region with a geometric diffraction and compositional discontinuity. Propagation of a detonation into such a region is very complex but critical to the re-establishment of the detonation wave in the JP-10/air mixture.

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A high-speed camera was used to image the wave in the transition region and provide spatial information. High frequency pressure transducers were used along the combustor axis to determine wave speed. The ultimate goal was to determine the conditions required to ensure reliable re-establishment of a detonation wave in the JP-10/air aerosol mixture.

Unfortunately, the confined planar JP-10/oxygen detonations in the pre-detonator were unable to transition into unconfined spherical detonation fronts in the JP-10/air aerosol. Furthermore, the ratio of main combustor diameter to pre-detonator diameter was too large to allow re-initiation of detonation at the main combustor wall.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: JP-10, Detonations, Pulse Detonation Engines, Tactical Missile Propulsion

SYSTEM ENGINEERING ASPECTS OF VTOL ROTORCRAFT: AN EXTENSION OF THE SIKORSKY ASSET CONCEPT DESIGN TRADE STUDY FOR THE UNITED STATES COAST GUARD DEEPWATER PROGRAM

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Master of Science in Aeronautical Engineering-March 2000

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Second Reader: Lynn M. Tinker, Sikorsky Aircraft Corporation

This thesis develops and uses systems engineering methods for the selection of vertical takeoff and landing (VTOL) rotorcraft for a specified mission. It proposes a general process for performing design trade studies as they apply to the selection of the Medium Range Rotorcraft (MRR) and Ship Based Unmanned Air Vehicle (SUAV) assets that are best suited in fulfilling the United States Coast Guard's Integrated Deepwater System (IDS) Concept of Operation (CONOPS). This thesis defines the phases that encompass a comprehensive trade-off analysis process. This thesis also describes an example of this process as used in the MRR and SUAV asset selection for the Sikorsky Deepwater Phase IA proposal. A method of validating the affordability criteria of the trade study through a derived life cycle cost (LCC) cost estimating relationship (CER) is formulated through the use of multiple variable regression analysis. A method of validating the flight performance criteria of the trade study is proposed using mission profile modeling and simulation (M&S). The Taguchi Method is used to analyze parameter sensitivity effects in the LCC model, and a selection criteria weight factor sensitivity analysis is conducted on the Trade Study Element Matrix.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Trade-off Analysis Process, Deepwater, Cost Estimating Relationship (CER)

UNMANNED AERIAL VEHICLES AND SPECIAL OPERATIONS: FUTURE DIRECTIONS

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Master of Science in Defense Analysis-December 2000

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Second Reader: E. Roberts Wood, Department of Aeronautics and Astronautics

Advances in computing, miniaturization, imaging, and data transmission technologies are precursors to a more important role for UAVs in warfare. UAVs are likely, first, to revolutionize the way reconnaissance and surveillance are conducted, second to increase the capabilities of small units, third to join manned platforms in the conduct of assault and attack missions, and finally help provide the numerous nodes necessary to facilitate both the digital connectivity and swarming forces envisioned in future networkcentric formations.

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This thesis focuses on answering six questions:

- What missions can UAVs perform?
- What missions should UAVs perform?
- What type of UAV is appropriate for each mission?
- How can SOF use UAVs?
- Who should own the UAV (from a SOF perspective)?
- What level of control is required and where?

Results include what UAV missions and types could support special operations, which of these should be performed by UAVs organic to special operations, and which should be performed by the Services' UAVs, as well as recommendations for future command and control of UAVs supporting special operations. Results are presented in matrix form for easy correlation of related factors. The thesis concludes with a twenty-year prognostication of UAV development and recommends areas for future study.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Battlespace Environments, Command and Control and Communications, Electronic Warfare, Sensors

KEYWORDS: Unmanned Aerial Vehicles, UAV, Special Operations Forces, SOF, Future of Warfare

A PROJECTILE FOR A RECTANGULAR BARRELED RAIL GUN

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William B. Maier, II, Department of Physics

The Physics Department at the Naval Postgraduate School is developing a concept to overcome the problems that keep present rail guns from being practical weapons. The rails must be replaced often if the rail gun operation is to be continuous. Replacing the rails in present rail gun configurations is time consuming. The Physics Department's design concept uses a rectangular barrel as part of the solution to the problem of replacing the rails. The projectile will require flat surfaces to maintain electrical contact with the flat rails and aerodynamic stabilization because of the lack of angular momentum. This thesis develops one possible model of a projectile for a rectangular barreled rail gun, which could be used to replace the standard five-inch gun found on most warships. The proposed projectile is successfully modeled as a five inch projectile with flat areas planed onto opposite sides and long chord, short span fins attached in a cruciform configuration. The computer programs used to develop the projectile model are included to allow evaluation of alternate configurations.

DOD KEY TECHNOLOGY AREAS: Conventional Weapons, Modeling and Simulation

KEYWORDS: Projectiles, Rail Guns, Computer Modeling

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DESIGN, CHARACTERIZATION, AND PERFORMANCE OF A VALVELESS PULSE DETONATION ENGINE

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Second Reader: David W. Netzer, Department of Aeronautics and Astronautics

Current interest in developing a low cost, less complex tactical missile propulsion system that operates on readily available liquid fuels and can operate from low subsonic to a flight Mach number of 5 is driving research on pulse detonation engines.

This research program involved the design, construction, and testing of a valveless Pulse Detonation Engine using a JP-10/air mixture as the primary combustible reactants. A small JP-10/oxygen pre-detonation tube was used to initiate the detonation in the JP-10/air mixture in the engine. The engine was tested at various inlet conditions and equivalence ratios in order to determine the detonable regime of the fuel/air mixture. The original area transition from the pre-detonation tube to the main combustion tube appeared to be too extreme, so a tube was added to extend the pre-detonation tube into the throat of a shock focusing device inserted flush with the head end of the main combustion tube to promote more favorable transition conditions.

In addition, the effects of a transient detonation process on the inlet operation and performance of the engine was theoretically predicted, using a two dimensional grid in a viscous computational fluid dynamics code, and experimentally evaluated from subsonic to supersonic operation.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Pulse Detonation Engine, JP-10, Liquid Fuels, Combustion

UH-60 BLACK HAWK DISTURBANCE REJECTION STUDY FOR HOVER/LOW SPEED HANDLING QUALITIES CRITERIA AND TURBULENCE MODELING

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Second Reader: Chris L. Blanken, Army/NASA Rotorcraft Division, NASA Ames Research Center

Helicopters operate in an environment where task performance can easily be affected by atmospheric turbulence. This paper discusses the airborne flight test of the Sikorsky UH-60 Black Hawk helicopter in turbulent conditions to determine disturbance rejection criteria and to develop a low speed turbulence model for helicopter simulation. A simple approach to modeling the aircraft response to turbulence is described by using an identified model of the Black Hawk to extract representative control inputs that replicate the aircraft response to disturbances. This parametric turbulence model is designed to be scaled for varying levels of turbulence and utilized in ground or in-flight simulation. Flight control cutoff frequency data are also analyzed to support design criteria for gust rejection handling qualities.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: Low Speed Helicopter Handling Qualities, Turbulence Modeling, Cutoff Frequency, Flight Control Design Requirements

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DARK CURRENT ANALYSIS AND COMPUTER SIMULATION OF TRIPLE-JUNCTION SOLAR CELLS

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Master of Science in Electrical Engineering-December 1999

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Oscar Biblarz, Department of Aeronautics and Astronautics

Second Reader: Todd Weatherford, Department of Electrical and Computer Engineering

This thesis reports the steps taken to characterize the semiconductor properties of triple-junction solar cells. Chemically etching the solar cells exposes each of the three energy producing junctions, InGaP, GaAs and Ge, to probes. Dark current measurements reveal the diode ideality factors of each junction, and these results are compared to current theories on diodes and solar cells. Calculations performed on experimentally obtained values from previous studies and measured values from this research for individual junctions show an expected diode ideality factor for the entire solar cell of 6.2 to 6.4, which is close to the actual production cell value of 5.9. Silvaco International's semiconductor simulation software was used to model the solar cell under dark and illuminated conditions. The simulated dark current yields an ideality factor of 3.45—lower than expected. A spectral analysis equating wavelength of light to current production for each junction within the solar cell is presented, and methods to better match the current produced from each junction are investigated. A current-versus-voltage-curve comparison equates simulated results to actual manufactured cell performance under illumination conditions; simulated values were within 10% for V_{oc} and 15% for I_{ss} in the better performing junctions.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Solar Cell, Multijunction, Tunneling, Software Simulation, Dark Current, GaAs, InGaP, GaInP, Ge

A COMPUTATIONAL AND EXPERIMENTAL INVESTIGATION OF FLAPPING WING PROPULSION

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Master of Science in Aeronautical Engineering-March 2000

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Flapping-wing propulsion is studied experimentally and numerically. The objective of the research is to provide further insight into the aerodynamics of flapping-wing air vehicles. Experimental work is conducted in the NPS 1.5 m x 1.5 m (5 ft x 5 ft) in-draft wind tunnel. A previously constructed long-span flapping-wing model suspended by cables is used to approximate the two-dimensional nature of the numerical simulation. For this experiment, the model is configured with two wings executing plunge-only motion. Thrust is indirectly determined by using a laser rangefinder to measure streamwise displacement of the model. Results are compared with previous experimental tests. A numerical analysis is conducted using USPOT, a locally developed unsteady panel code that models two independently moving airfoils with three degrees of freedom and non-linear deforming wakes. Thrust and efficiencies are computed for harmonically oscillating airfoils. Direct comparison is made between experimental and numerical thrust measurements.

DOD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Flapping Wing, Low Reynolds Number, USPOT, Panel Code, Laser Doppler Velocimetry, LDV

THESIS ABSTRACTS

EVALUATION OF THE USE OF GPS-AIDED WEAPONS TO ATTACK MOVING TARGETS

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The current intelligence gathering and strike decision infrastructure is optimized to handle geographically and temporally fixed targets. When tasked to respond to targets that require near immediate engagement, however, the system is stressed to the limit of its capability. When these time sensitive targets are capable of relocating, the process of rapidly applying lethal force becomes even more complicated. This thesis examines the problems associated with attacking a moving target using low cost GPS-aided standoff weapons, without an integrated weapon seeker. It begins with a discussion of the history and evolution of the Navy's ability to attack time sensitive moving targets, and provides the description of a system that could address shortcomings noted. MATLAB® Simulink® was used to develop a model to simulate the proposed system, and determine the responses to various combinations of identified error sources. The results of the research showed that the type of system proposed is technically feasible.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Command, Control and Communications, Conventional Weapons, Sensors, Modeling and Simulation, Time Critical Strike, Other (Time Critical Strike)

KEYWORDS: GPS, Weapons, Modeling, CEP, Time Sensitive Targets, Command, Control and Communications, Conventional Weapons, Sensors, Modeling and Simulation, Time Critical Strike, Stand-off Weapons

CALIBRATION TO DETERMINE PRESSURE AND TEMPERATURE SENSITIVITIES OF A PRESSURE-SENSITIVE PAINT

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In order to obtain quantitative surface pressure measurements of a transonic compressor rotor using pressure sensitive paint (PSP), the temperature dependence of the paint must be taken into consideration. In the present study, a calibration chamber was built and instrumented such that pressure and temperature could be controlled independently. Photodiodes were used to measure the intensity of light emitted by the PSP. An acquisition program was developed to record the necessary calibration data to obtain an analytical representation of the luminescent response of the pressure-sensitive paint over a range of pressures and temperatures characteristic of transonic fans.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Pressure-Sensitive Paint, Photoluminescence, Luminescence, PtOEP, UV Illumination, Detection, Emission, Aerodynamics, Measurements, Temperature and Pressure Calibration

THESIS ABSTRACTS

EA-6B FOLLOW-ON STUDY: UAVS AND UCAVS

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Master of Science in Aeronautical Engineering-June 2000

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Second Reader: Phillip E. Pace, Department of Electrical and Computer Engineering

The DoD's only air-based EA jamming capability is provided by 123 EA-6B Prowlers. It is projected that these 123 aircraft will no longer adequately support required Airborne Electronic Attack (AEA) missions beyond the year 2010 due to attrition and airframe life limits. In order to maintain the tactical advantage over enemy air defenses, the DoD must augment and ultimately replace its aging and diminishing fleet of EA-6B aircraft with an equal or better AEA capability. Integrated Product Teams (IPT) are conducting an Analysis of Alternatives (AOA) to define operational requirements that address the DoD's AEA needs. The principal contribution of this thesis is to identify those unmanned aerial vehicles (UAVs) and unmanned combat aerial vehicles (UCAVs) that can be utilized in the future for AEA. UAV Electronic Warfare (EW) payloads and smart weapons that could help in this area are presented as well. While much has already been written concerning UAVs, few resources exist that discuss the feasibility of UAV programs in the realm of EW. Even fewer resources discuss how these unmanned platforms must be linked in the future to conduct network-centric warfare. This thesis attempts to bridge that gap.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Electronic Warfare, Other (Airborne Electronic Attack)

KEYWORDS: Airborne Electronic Attack, EA-6B, Electronic Attack, Electronic Warfare, Jamming, Network Centric Warfare, Payloads, Precision Guided Weapons, Smart Weapons, UAV, UCAV

TRANSONIC COMPRESSOR TEST RIG REBUILD AND INITIAL RESULTS WITH THE SANGER STAGE

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Master of Science in Aeronautical Engineering-June 2000

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The NPS Transonic Compressor Test Rig was rebuilt and initial testing was conducted on the Sanger Stage, which was designed using CFD techniques. Improvements to the existing monitoring equipment, test rig instrumentation, and data acquisition software were all made in preparation for testing. A Plexiglas casewall was chosen to accommodate pressure-sensitive paint measurements. Wall heating was used to control tip-clearance. The initial performance data, to 70% design speed, were compared with predictions using a 3-dimensional viscous code.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Compressor, Transonic, CFD, Turbomachinery, Tip Clearance

THESIS ABSTRACTS

IMPLEMENTATION OF A TWO PROBE TIP-TIMING TECHNIQUE TO DETERMINE COMPRESSOR BLADE VIBRATIONS

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This study involved the implementation and validation of a blade-tip time of arrival (TOA) measurement technique, and the development of a computer program to analyze TOA data using a recently published approach. The program was used to analyze experimental compressor data taken in-house using two laser light probes, data generated computationally, and data obtained by others in a compressor test. The in-house compressor data was compared successfully to amplitudes obtained by strobed digital photography. A resonance was successfully detected in the supplied compressor data set.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Tip-timing, Non-Contact Measurement, Blade Vibration

ANGULAR RATE ESTIMATION FOR MULTI-BODY SPACECRAFT ATTITUDE CONTROL

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Master of Science in Astronautical Engineering-June 2001

Aeronautical and Astronautical Engineer-June 2001

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Spacecraft with high performance attitude control systems requirements have traditionally relied on imperfect mechanical gyroscopes for primary attitude determination. Gyro bias errors are connected with a Kalman filter algorithm that uses updates from precise attitude sensors like star trackers. Gyroscopes, however, have a tendency to degrade or fail on orbit, becoming a life-limiting factor for many satellites. When Errors become erratic, pointing accuracy may be lost during short star gaps. Unpredictable gyros degradations have impacted NASA spacecraft missions such as Skylab and Hubble Space Telescope as several DoD and ESA satellites. An alternative source of angular rate information is a software implemented real time dynamic model. Inputs to the model from internal sensors and known spacecraft parameters enable the tracking of total system angular momentum from which body rates can be determined. With this technique, the Kalman filter algorithm provides error corrections to the dynamic model. The accuracy of internal sensor and input parameters determine the effectiveness of this angular rate estimation technique. This thesis presents the background for understanding and implementation of the technique into a representative attitude determination system. The system is incorporated into an attitude simulation model developed in SIMULINK to evaluate the effects of dynamic modeling errors and sensor inaccuracies. Results are presented that indicate that real time dynamic modeling is an effective method of angular rate determination for maneuvering multi-body spacecraft attitude control systems.

DOD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation

KEYWORDS: Dynamic Gyro, Kalman Filter, Attitude Determination, Rate Estimation, Star Trackers, Attitude Simulation, Multi-body Dynamics, MATLAB, SIMULINK

THESIS ABSTRACTS

SPACECRAFT INTEGRATED DESIGN TOOLS

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The thesis surveys current software tools to design satellites and develops an integrated spreadsheet-based tool for preliminary spacecraft design. First, several existing and future design tools - both commercially available and company proprietary - are discussed and evaluated. Second, a spreadsheet-based design tool which is generally applicable to any earth-orbiting satellite is developed. Preliminary design of all satellite subsystems is performed on separate sheets of the Excel workbook. Based on user-entered orbital data propellant and mass budgets are also calculated. The design technique and spreadsheet implementation is presented along with the underlying "first principles" theory and equations.

DOD KEY TECHNOLOGY AREAS: Space Vehicles, Computing and Software

KEYWORDS: Spacecraft, Satellites, Design Tools, Concurrent Engineering

ACTIVE VIBRATION CONTROL METHOD FOR SPACE TRUSS USING PIEZOELECTRIC ACTUATORS AND FINITE ELEMENTS

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Master of Science in Astronautical Engineering-December 1999

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This thesis created an analytical model for active vibration control of the NPS space truss using ANSYS. The NPS space truss is a 3.7-meter long truss that simulates a space-borne appendage with sensitive equipment at its extremities. With the use of a dSPACE data acquisition and processing system, quartz force transducer and piezoelectric actuator, active controls using an integral plus double integral control law were used to damp out the vibrations caused by a linear proof mass actuator. Vibration reductions on the order of 15-20 dB were obtained with experiment.

The ANSYS finite element model used SOLID5 elements to model the piezoelectric characteristics and ANSYS Parametric Design Language to provide for an iterative approach to an active controls analysis. Comparative data runs were performed with the ANSYS model to determine its similarity to experiment. The analytical model produced power reductions of 18-22 dB, demonstrating the ability to model the control authority with a finite element model. This technique can be used and modified to enhance its flexibility to many types of controls and vibration reduction applications. An analytical model for active control of the NPS space truss using MATLAB/Simulink was also developed as an alternative to the ANSYS model.

DOD KEY TECHNOLOGY AREAS: Space Vehicles, Materials, Processes and Structures, Modeling and Simulation

KEYWORDS: Active Vibration Control, Piezoceramic Actuators, ANSYS, Finite Element Method

THESIS ABSTRACTS

THE NPS SPACECRAFT COST MODEL: TAILORING CURRENT COMMERCIAL SPACECRAFT COST MODELS FOR NAVAL POSTGRADUATE SCHOOL SATELLITE PROGRAMS

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Alfred N. Sorensen, National Reconnaissance Office Chair Professor

The successful launch of the Naval Postgraduate School (NPS) Petite Amateur Navy Satellite (PANSAT) led to the development of a follow-on satellite program at NPS. Until now, there did not exist a NPS specific cost modeling procedure to ensure accurate pricing information for program management. From the Preliminary Design Review of NPSat an initial attempt at modeling this program was conducted by the author. This thesis will provide an evaluation of this initial model and address procedures for refining the initial estimate with the purpose of providing a generic NPS Cost Model. This model will tailor current commercial cost model outputs to provide accurate price estimates for NPS specific programs. The commercial cost models used were Science Applications International Corporation's (SAIC) NAFCOM model and Aerospace's Small Satellite Cost Model (SSCM). These models do not take into account a university atmosphere where staffs and facilities are reduced. A method of tailoring the outputs of these programs was conducted and integrated into an Excel based spreadsheet. The resultant product is the Naval Postgraduate School's first Cost Modeling program which allows NPS satellite program management to input results from the SSCM and NAFCOM models and output expected cost data.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Spacecraft Cost Modeling, Parametric Estimation, Satellite Design

TARGETING AND FIRE CONTROL SYSTEM ANALYSIS OF THE NEW TURKISH ATTACK HELICOPTER "THE AH-IZ KINGCOBRA"

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Alfred W. Cooper, Department of Physics

In May of 1997, the Turkish Military issued a Request for a Proposal for the purchase of 145 attack helicopters. Turkey has chosen Bell Helicopter's KingCobra as its attack helicopter. The major difference between the USMC version of the AH-IZ and the Turkish version KingCobra is the Targeting and Fire Control System. Bell helicopter Textron has chosen Lockheed Martin to develop and build a new targeting system, the Target Sight System (TSS). The TSS will contain Lockheed Martin's 3-5 μ m midwave staring array FLIR. On the other hand, the Turkish Secretariat for Defense Industries (SSM) has chosen Aselsan ASEFLIR-300T that contains an 8-12 μ m longwave scanning second-generation FLIR.

A comparison of range performance for these two systems has been made using the TAWS Field Performance Model. Since the physical parameters on these specific FLIRs are proprietary, the FLIR92 Simulation Model is used to generate performance parameters. These parameters are expected to represent the general characteristics of the two systems. The resultant data is used in the TAWS Field Performance Model to predict the range performances.

The results have shown that the staring array midwave FLIR has longer ranges in the scenarios given in this thesis. This may not represent the real performance of the systems.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Sensors, Other (Thermal Imaging Systems)

KEYWORDS: Thermal Imaging Systems, Targeting, Fire Control Systems, Forward Looking Infrared, FLIR, TAWS, KingCobra, Attack Helicopter, Infrared

THESIS ABSTRACTS

INFLUENCE OF IGNITION ENERGY, IGNITION LOCATION, AND STOICHIOMETRY ON THE DEFLAGRATION-TO-DETONATION DISTANCE IN A PULSE DETONATION ENGINE

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The feasibility of utilizing detonations for air-breathing propulsion is the subject of a significant research effort headed by the Office of Naval Research. Pulse Detonation Engines (PDE) have a theoretically greater efficiency than current combustion cycles. However, pulse detonation technology must mature beginning with research in the fundamental process of developing a detonation wave. This thesis explores various ignition conditions which minimize the deflagration-to-detonation transition distance (X_{DDT}) of a single detonation wave in a gaseous mixture.

Specifically, the minimum X_{DDT} was determined for different Ethylene and Oxygen/Nitrogen gaseous mixtures under varying ignition energy (0.33-8.31 Joules), mixture equivalence ratios (0.6-2.0), and ignitor locations. To conduct the experiments a 6 feet long, 3 inch diameter tube combustor, support equipment, and operating software was built. Four independent test scenarios were investigated and trends developed to determine the minimum X_{DDT} while reducing oxidizer blend ratios.

Results show that X_{DDT} significantly depends on mixture equivalence ratio (ϕ) and was minimized at $\phi \approx 1.1$. No dependence on ignition energies greater than 0.5 Joules was observed. A further reduction in X_{DDT} was observed with the ignitor located one combustor diameter from the head wall. These results will be useful in future designs of pre-detonators for larger PDEs.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Detonation, Pulse Detonation Engine, Deflagration-to-Detonation Transition, DDT

PROTOTYPE DESIGN OF NPSAT VISIBLE IMAGER

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Master of Science in Astronautical Engineering-June 2000

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Second Reader: Brij N. Agrawal, Department of Astronautical Engineering

The objective of this work was to design and construct a prototype imager for the NPS remote sensing satellite. This project is a low-earth orbiting satellite designed to image the earth in VNIR and LWIR at a resolution of 100-200 m.

The specific imager design considered here is the VNIR instrument, designed to image the daylit earth and atmosphere, as well as the relatively dim aurora (northern lights) at multiple discrete wavelengths. This project defined the desired wavelengths to be: 427.8 nm, 470.9 nm, 557.7 nm, 630.0 nm, 636.4 nm, and 844.6 nm.

A Kodak 763 X 512 CCD was implemented into a push-broom scanner design appropriate for our mission. Design optics are for a nominal F/2, 90 mm Leica lens. The prototype was completed and demonstrated to operate.

DOD KEY TECHNOLOGY AREAS: Sensors, Electronics

KEYWORDS: Satellite, Imager, Aurora, Optics

THESIS ABSTRACTS

FEASIBILITY OF TWO-GIMBAL PLATFORM TUMBLING TO MINIMIZE VELOCITY ERROR (U)

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Second Readers: Peter Howard, Charles Stark Draper Laboratory

Andrew Staugler, Charles Stark Draper Laboratory

Abstract is classified.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Space Vehicles, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Gimbal Tumbling, Trajectory Optimization

MEASUREMENT OF FUEL ADDITIVE EFFECTS ON THE SOOT MASS LOADING IN OXYGEN/KEROSENE EXHAUST PLUMES

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David W. Netzer, Department of Aeronautics and Astronautics

D. Scott Davis, Department of Physics

Measurements of the soot mass loading in the exhaust of a small liquid rocket engine burning gaseous oxygen with kerosene and kerosene with additive mixtures have been made. The rocket engine was operated over a high soot-producing regime, to simulate the film-cooling region of an actual system, which covered an oxygen-to-fuel ratio (O/F) range of 0.6 to 1.3 and produced a nearly uniform plume distribution. Using a dual fuel tank system, the fuel source was switched during the runs to allow both kerosene and kerosene with additive measurements to be conducted during the same run to ensure nearly identical engine operating conditions. A multi-wavelength optical transmission technique was used to determine the amount of soot present and utilized the transmission ratio of six wavelengths from the near UV to the visible through the plume of the engine. The experimental technique was analyzed to determine the potential error introduced when the transmission values were extremely low (<5%) and what potential effect any organic absorbers (PAHs) may have had on the transmission ratios for the near UV wavelengths. Experimental results show that the addition of as little as 1% by mass of an additive can significantly reduce the amount of soot present in the engine exhaust, and therefore alter the associated IR radiation from the plume.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Soot Measurement, Kerosene/Oxygen Liquid Rocket Engines, Additive Effects

THESIS ABSTRACTS

MICROELECTROMECHANICAL SYSTEMS FOR SMALL SATELLITE APPLICATIONS

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Master of Science in Astronautical Engineering-June 2001

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Brij Agrawal, Department of Aeronautics and Astronautics

Second Reader: Alfred N. Sorensen, National Reconnaissance Office, Chair Professor

Microelectromechanical systems (MEMS) have been developing for the past few decades, but recent spaceflight demonstrations have highlighted the potential of this technology as an attractive paradigm shift in how aerospace systems should be developed, maintained and used as the dawn of a new space age emerges. MEMS will generate a revolution in the way people see and control tomorrow's satellites by combining technological advances in sensors, actuators, reactionary systems, spacecraft attitude control systems, information processing and storage with the miniaturization of these components. MEMS will enable the realization of decentralizing satellites and, therefore, create a paradigm shift in the conceptual operation and development process of how people think about using satellites. The vision of what can be achieved from space is no longer bound by what an individual satellite can accomplish, rather, a number of production. This thesis will validate the concepts of MEMS and its applicability to space and conclude by examining possible paths that the Naval Postgraduate School microsatellite, NPSAT1, can take to reducing subsystem power through the use of MEMS components.

DOD KEY TECHNOLOGY AREAS: Sensors, Other (Microelectromechanical Systems)

KEYWORDS: Microelectromechanical Systems, MEMS, Nanosatellites, Microsatellites, NPSAT1, Gyroscopes

EXPLOITATION OF NATIONAL SENSORS FOR TERRAIN CATEGORIZATION (U)

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Abstract is classified.

DOD KEY TECHNOLOGY AREAS: Space Vehicles, Sensors, Other (Intelligence, Indications and Warning (I&W))

KEYWORDS: Sensor Fusion, Multispectral Imaging, Imagery Intelligence, TERCAT

SIMULATION OF GUIDED AEROASSISTED MANEUVERS FOR PLANETARY MISSIONS

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Second Reader: S.E. Matousek, Jet Propulsion Laboratory

Aeroassisted maneuvers are distinguished from purely propulsive maneuvers in that aerodynamic forces are used to assist in orbital maneuvers of spacecraft. These types of maneuvers can vary from aerocapture to direct entry. The NASA Solar System Exploration Program lays the foundation for the future of interplanetary exploration using various versions of these aeroassisted maneuvers. The computer program

THESIS ABSTRACTS

ACAPS, designed at the Naval Postgraduate School, was developed for the Jet Propulsion Laboratory (JPL) to conduct high-level mission design for exploration missions to Mars. The primary research objective of this thesis was to upgrade the previous version of ACAPS, to produce a tool that provides new capabilities in support of the Solar System Exploration Program. The secondary research objective of this thesis was to provide direct support to JPL mission planners. The first major upgrade was the incorporation of additional planets which allows for simulation at Venus, Saturn, Neptune and Titan. The second focus of work was the incorporation of guidance to include ballute guidance and the Apollo derived Mars Precision Lander guidance algorithm. This thesis also documents how these upgrades were used to support future missions to Venus, Neptune, Saturn and Titan; particularly in the possibilities of using ballutes.

DOD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation

KEYWORDS: Aerocapture, Simulation (ACAPS), Aeroassist, National Aeronautics and Space Administration (NASA), Jet Propulsion Laboratory (JPL), Mars Sample Return (MSR) Mission, Mars Micromission, MATLAB, SIMULINK, Ballute, Parachute

DETONABILITY OF HYDROCARBON/AIR MIXTURES USING COMBUSTION ENHANCING GEOMETRIES FOR PULSE DETONATION ENGINES

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Master of Science in Applied Physics-June 2001

Advisors: Christopher M. Brophy, Department of Aeronautics and Astronautics

James V. Sanders, Department of Physics

Second Reader: David W. Netzer, Department of Aeronautics and Astronautics

This research studied combustion enhancing geometries and shock reflection on generating a hydrocarbon/air detonation wave in a combustion tube. Ethylene was used as a baseline fuel to determine the heavy hydrocarbon fuels such as JP5, JP8, and JP10. Three criteria were used to measure the effectiveness of the combustion enhancing geometries: ability to generate a detonation, wave speed, and time for shock formation. The evaluated geometries included flow-restricting orifice plates and a Schelkin spiral. Detonations occurred when using ethylene in this configuration, but did not develop when using propane. Because propane's overall reaction rate is slower than that of simpler fuels, more larger- and small-scale turbulence to further enhance combustion needs to be generated to create a detonation wave in a short distance when using complex hydrocarbons, such as propane.

DOD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Detonation, Pulse Detonation Engine, Deflagration to Detonation Transition, DDT

COMPUTERIZED BALLISTIC MODELING OF THE COMANCHE TAILFAN SHROUD

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Donald A. Danielson, Department of Mathematics

The U.S. Army has contracted Boeing-Sikorsky to develop the RAH-66 Comanche, a new, armed reconnaissance helicopter that features stealth technology designed to improve survivability when operating in hostile environments. Ballistic testing is required on the Comanche prior to fielding. Computer based simulations are being employed in order to reduce requirements for expensive live-fire testing. This thesis uses a computer program called Dytran from MacNeal-Schwendler to simulate the effects of an explosive round detonating in the Comanche tailfan shroud. Six test cases involving explosions with varying

THESIS ABSTRACTS

amounts of explosive energy, or specific internal energy, are evaluated. From these tests, a curve showing the percentage of structural failure versus the specific internal energy is plotted. Assuming that 20% structural failure of the model equates to a catastrophic failure, this analysis shows that the analyzed section of the Comanche tailfan shroud can withstand an explosion with a specific internal energy of $2.58 \times 10^{10} \text{ in}^2/\text{sec}^2$. Any potential threat rounds with specific internal energies greater than $2.58 \times 10^{10} \text{ in}^2/\text{sec}^2$ will pose serious threats to the Comanche.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Materials, Processes and Structures, Modeling and Simulation

KEYWORDS: Comanche, Ballistic Modeling, Dytrain, Tailfan Shroud

QUALITY FUNCTIONAL DEPLOYMENT AS A CONCEPTUAL AIRCRAFT DESIGN TOOL

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Master of Science in Aeronautical Engineering-March 2000

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Second Reader: Russ W. Duren, Department of Aeronautics and Astronautics

Quality Functional Deployment (QFD) methodology was applied as a possible system integration tool for use during the conceptual configuration design phase of low speed High Altitude Long Endurance (HALE) UAVs. A four-level QFD model was used to identify important design variables and prioritize those that impact customer attributes. The customer attributes were deployed into performance parameters. The performance parameters were deployed into UAV part characteristics. The part characteristics were deployed into manufacturing processes. The manufacturing processes were deployed into process controls. Based on QFD, the research effort showed that to achieve the customer attributes of high endurance, range, cruise altitude and payload, the important performance parameters are low gross weight, low $C_{D,0}$, high $C_{L,max}$ and a low life cycle cost. The part characteristics considered for the conceptual HALE UAV configuration were maximum utilization of composites, thick airfoil (to increase fuel capacity), high wing fatigue strength and low wing sweep. To achieve the part characteristics, the manufacturing methods considered were autoclaving and filament winding for composites components; milling and precision forging were considered for aluminum alloy components. Manufacturing process controls were also identified. In each QFD matrix, the technical correlations "roof" provided an effective mechanism for comparing each design parameter against other design parameters in order to determine conflicting design requirements.

DoD KEY TECHNOLOGY AREA: Other (Aircraft Design)

KEYWORDS: Quality Functional Deployment, Aircraft Design, Uninhabited Aerial Vehicle

REMOTE NANOSATELLITE FORMATION DESIGNS WITH ORBIT PERTURBATION CORRECTION AND ATTITUDE CONTROL/PROPULSION SUBSYSTEM CORRELATION

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B.S., Rensselaer Polytechnic Institute, 1994

Master of Science in Astronautical Engineering-June 2001

Advisor: Brij N. Agrawal, Department of Aeronautics and Astronautics

Second Reader: Alfred N. Sorenson, National Reconnaissance Office Chair Professor

The innovative idea of distributing the functionality of current larger satellites among smaller, cooperative satellites has been sincerely considered for assorted space missions to accomplish goals that are not possible or very difficult to do with a single satellite. Additionally, the utilization of smaller satellites is

THESIS ABSTRACTS

maximized within formations and clusters to conduct missions such as interferometry and earth-sensing. This paper presents a methodology to describe, populate and analyze numerous formation designs employing the use of Hill's equations of motion to describe a formation's dynamics. These equations of motion are then programmed into a MATLAB code to produce Cartesian elements for input into a Satellite Tool Kit™ (STK) simulation that demonstrates numerous possible cluster formation designs. These simulations are then used to determine ΔV requirements for overcoming LEO-type perturbations that were modeled within STK's High Precision Orbit Propagator (HPOP).

Finally, components from two subsystems [Attitude Determination and Control (ADCS) and Propulsion], using the ΔV calculations from the simulation analysis and current advances in MicroElectroMechanical systems (MEMS) and nanosatellite technology, are presented based on a mass constraint of 10kg for the entire satellite.

DOD KEY TECHNOLOGY AREAS: Aerospace Propulsion, Space Vehicles, Modeling and Simulation

KEYWORDS: Satellite Formation, Orbit Dynamics, STK, Nanosatellite, and Satellite Propulsion

ATTITUDE DETERMINATION OF A THREE-AXIS STABILIZED SPACECRAFT USING STAR SENSORS

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Master of Science in Astronautical Engineering-December 1999

Advisors: Harold A. Titus, Department of Electrical and Computer Engineering
Brig N. Agrawal, Department of Aeronautics and Astronautics

The purpose of this thesis is to investigate the application of a six-state discrete Kalman filter for estimates of angular rates based solely on star sensor data. The satellite is in a Molnyia orbit where orbital angular velocity and orbital angular acceleration are predetermined and stored in the on-board computer; such that they will be available each time a star observation is made. A two-axis star sensor will provide two angles to the estimator whereupon the third "unsensed" angle will be predicted; the rates about all three axes are then estimated. The results show that the rate estimates are accurate to within 10^{-7} r/s, which is equivalent to the data produced by gyroscopes.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Kalman, Molnyia, MATLAB, Spacecraft, Satellite, Star Sensor, Star Tracker, Estimation, Rate, Gyroscope

FULL NONLINEAR SIMULATION OF HELICOPTER COUPLED ROTOR-FUSELAGE MOTION USING MATLAB® AND DYNAMIC SIMULATION

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Master of Science in Aeronautical Engineering-March 2000

Advisors: E. Roberts Wood, Department of Aeronautics and Astronautics
Robert L. King, Mississippi State University

This thesis formulates the full nonlinear equations of motion for determining the stability of helicopter coupled rotor-fuselage motion utilizing MATLAB®'s Symbolic Math Toolbox. Using the extended symbolic processor toolbox, the goal of this work was to eliminate the time consuming process of converting Fortran or C code generated by the symbolic processor, MAPLE® into a MATLAB® useable format where it is further incorporated into an 'S-function' to be used in the dynamic simulation environment.

THESIS ABSTRACTS

The formulation of the equations of motion utilized in this process is unique in that it uses the complete set of nonlinear terms in the equations of motions without utilizing ordering schemes, small angle assumptions, linearizing techniques, or other simplifying assumptions. After derivation, the equations of motion are numerically integrated using the dynamic simulation software SIMULINK® and a time history plot is generated of blade and fuselage motion. The equations of motion are regenerated with each time step allowing the adjustment of characteristic structural, blade and dampening properties. These time traces can be used to explore the effects of damping nonlinearities, structural nonlinearities, active control, individual blade control, and damper failure on ground resonance.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Modeling and Simulation

KEYWORDS: MATLAB® Symbolic Processor, Helicopter, Ground Resonance, Nonlinear Simulation, Computer Modeling

A STUDY OF THE FEASIBILITY AND APPLICABILITY OF SHAPE CONTROLLED SPACE BASED INFLATABLE MEMBRANE STRUCTURES

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Master of Science in Astronautical Engineering-September 2000

Master of Science in Space Systems Operations-September 2000

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Inflatable structures used for space applications offer mass, volume, and cost savings to spacecraft programs, allowing larger space structures to be built. For certain space applications, there are advantages to using large structures. For example, antennas achieve higher gains when they are increased in size. Higher gains equate to higher data throughputs. Therefore, inflatable structures offer improvements in performance to certain types of spacecraft components.

Environmental factors induce surface errors on large inflatable structures. This degrades performance, especially for inflatable antennas. To reduce this degradation, active and passive control systems can be used to sense errors and control the shape of the antenna. One method of applying an active and passive control system is by using piezoelectric films that are either attached to or are part of the inflatable structure.

The result performed for this thesis explored the theoretical performance of a large inflatable space-based antenna via spreadsheet analysis and the physical performance of a piezoelectric film via laboratory experimentation. For the laboratory experiment, the film was attached to a drum and varying internal pressures and voltages were applied. Also, in order to validate the experimental results, an analytical model was created using MSC/PATRAN and MSC/NASTRAN software.

DOD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Piezoelectric Film, Inflatable Structure, Antennas, Communications, Satellite Development

THESIS ABSTRACTS

OPTIMAL PARACHUTE GUIDANCE, NAVIGATION, AND CONTROL FOR THE AFFORDABLE GUIDED AIRDROP SYSTEM (AGAS)

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Master of Science in Aeronautical Engineering-June 2000

Advisor: Isaac I. Kaminer, Department of Aeronautics and Astronautics

Second Reader: Oleg A. Yakimenko, National Research Council Research Associate

This study is a continuation of a previous work concerning the Affordable Guided Airdrop System (AGAS), a parachute system that integrates low-cost guidance and control into fielded cargo air delivery systems. This thesis sought to expand upon the previous study and provide more information and research on this innovative and critical military system. Several objectives and tasks were completed in the course of this research and development. The simulation model used in the previous work for feasibility and analysis studies was moved from a MATLAB/SIMULINK® environment to a MATRIX-X® environment in anticipation of AGAS future use on an Integrated Systems, Incorporated AC-104 real-time controller. Further simulation and study for this thesis were performed on the new system. The new model implemented characteristics of the G-12 parachute, which eventually will be used in the actual flight testing of the AGAS airdrop. The system of pneumatic muscle actuators (PMSs) built by Vertigo, Incorporated, and used on the AGAS was modeled on the computer also. The characteristics of this system and their effects on AGAS guidance and control were studied in depth. The control concept of following a predicted trajectory based on certain wind predictions and other ideas for control algorithms to minimize fuel gas usage, number of control actuations and final control error were also studied. Conclusions and recommendations for further study were drawn from this project.

DOD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Parachute, Navigation Guidance and Control)

KEYWORDS: MATRIX-X® Software, Parachute, Guidance, Navigation, Control, Simulation, Wind Estimation

ANALYSIS OF TRACKING AND IDENTIFICATION CHARACTERISTICS OF DIVERSE SYSTEMS AND DATA SOURCES FOR SENSOR FUSION

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In the Command and Control mission, new technologies such as 'sensor fusion' are designed to help reduce operator workload and increase situational awareness. This thesis explored the tracking characteristics of diverse sensors and sources of data and their contributions to a fused tactical picture. The fundamental building blocks of any sensor fusion algorithm are the tracking algorithms associated with each of the sensors on the sensor platform. In support of this study, the MATLAB program '*fusion*' was written to provide acquisition managers a tool for evaluating tracking and sensor fusion algorithm.

The *fusim* program gives the user flexibility in selecting: sensor platforms, up to four sensors associated with that platform, the target types, the problem orientation, and the tracking algorithms to be used with the sensors. The *fusim* program was used to compare tracking algorithms in a multiple sensor/multiple target environment. Specifically, the Probabilistic Data Association Filter, the Interacting Multiple Model Filter, the Kalman Filter and the Constant Gain Kalman Filter were evaluated against multiple maneuvering, non-maneuvering, and fixed targets. It is recommended that this study be continued to evaluate advanced tracking and data association techniques, to expand the program to allow attribute tracking and identification, and to study the Human-Machine Interface aspects of sensor fusion.

THESIS ABSTRACTS

DOD KEY TECHNOLOGY AREAS: Modeling and Simulation, Sensors, Command Control and Communications, Computing and Software

KEYWORDS: Data Fusion, Sensor Fusion, Tracking, Tracking Algorithms, Kalman Filter, Probabilistic Data Association, PDA, Interacting Multiple Models, IMM, Simulation

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